DOCUMENT RESUME

ED 059 023 24 RE 003 991

AUTHOR Davis, Frederick B., Ed.
TITLE The Literature of Research in Reading with Emphasis on Models. Final Report.
INSTITUTION Rutgers, The State Univ., New Brunswick, N.J. Graduate School of Education.
SPONS AGENCY National Center for Educational Research and Development (DHEW/OE), Washington, D.C.
BUREAU NO BR-0-9030
PUB DATE 71
CONTRACT OEC-0-70-4790(508)
NOTE 640p.

EDRS PRICE MF-$0.65 HC-$23.03
DESCRIPTORS Educational Research; *Language Development; Language Research; Learning Theories; *Literature Reviews; *Models; Psycholinguistics; *Reading Processes; *Reading Research; Research and Development Centers; Research Reviews (Publications)

ABSTRACT

This final report of the Targeted Research and Development Program in Reading, Project 2, Literature Search, constitutes the results of a massive search of literature in the area of reading to find and synthesize all of the literature pertaining to models of reading development and process. General areas of models considered are language development and reading, learning to read, and the reading process. The first five sections describe the background and development of the search procedures, outline areas from which models are drawn and describe a number of models, and seek to synthesize the information obtained. The final sections contain 16 separate papers in the three general areas defined. Bibliographies follow each of the papers. (MS)

Targeted Research and Development Program in Reading
Office of Education
National Center for Educational Research and Development
United States Department of Health, Education, and Welfare
Washington, D.C.

Project No. 2: The Literature Search
Contract No. OEC-0-70-4790 (508)
Project No. 0-9030

Martin Kling, *Principal Investigator*

Frederick B. Davis, *Project Director*

John J. Geyer, *Associate Project Director*

Final Report

THE LITERATURE OF RESEARCH IN READING WITH EMPHASIS ON MODELS

Edited by:

Frederick B. Davis

University of Pennsylvania

Graduate School of Education
Rutgers--The State University
New Brunswick, New Jersey

1971

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the help of colleagues and supporting personnel who contributed their talent and enthusiasm to this project. They include:

Reviewer-Evaluators, whose signed contributions appear in Sections 6, 7, and 8 and whose names need not be repeated here.

Advisory Panel Members

Language Development:

David Elkind, University of Rochester
Richard E. Hodges, University of Chicago
Robert B. Ruddell, University of California, Berkeley

Learning to Read:

James E. Deese, The Johns Hopkins University
S. Jay Samuels, University of Minnesota
Harry Singer, University of California, Riverside

Reading Process:

Robert Efron, V.A. Hospital, Martinez, California
Albert J. Kingston, University of Georgia
Paul A. Kolers, University of Toronto
Karl H. Pribram, Stanford University

Research:

Jason Millman, Cornell University

Coordinators

Language Development:

Irene J. Athey, University of Rochester

Learning to Read:

Joanna P. Williams, University of Pennsylvania

Reading Process:

John J. Geyer, Rutgers University

Central-Office Personnel

Frederick B. Davis
John J. Geyer
Beatrice Mayes
Leny Struminger
John Nealon
Betty Karwan
Margaret Sandahl
Gloria Lukacs

Rutgers University Administration

Dean Milton Schwebel, Graduate School of Education
Dean Thomas Mott, Graduate School of Library Service
Mr. Albert Hanna, Research Contracts Office

Acknowledgment should also be made of the assistance given by Mr. Monte Penney, contract monitor in the U.S. Office of Education, and by Mrs. Anne McCartney of McCartney Printing Services.

Finally, I wish to thank my wife, Roslyn, and my children, Larry, Miriam, and Aaron, for their support.

Martin Kling
Principal Investigator

New Brunswick, New Jersey
August 30, 1971

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

SECTION 1

BACKGROUND AND DEVELOPMENT OF THE LITERATURE SEARCH: TARGETED RESEARCH AND DEVELOPMENT PROGRAM IN READING

Martin Kling

Rutgers University

INTRODUCTION

For convenience, this section is arranged in four parts, all pertaining to the Literature Search in Reading sponsored by the U.S. Department of Health, Education, and Welfare, Office of Education, National Center for Educational Research and Development. Part 1 highlights the reading-research efforts supported by the Office of Education; Part 2 discusses briefly the summaries of research findings and theory construction that preceded the present literature search; Part 3 describes the rationale and objectives of this literature search; Part 4 provides an overview of the strategies of and milestones in this literature search from July 1, 1970 to June 30, 1971.

PART 1: RESEARCH EFFORTS ON READING SUPPORTED BY USOE: 1957-1970

Summary of USOE Support

Penney, Hjelm, and Gephart (1970) recounted the history of support for research in reading by the U.S. Office of Education. They noted that from 1957-1968 nearly 12 million dollars were spent in support of 257 reading-research projects. Four categories of projects that received support from the National Center for Educational Research and Development and the Bureau of Education for the Handicapped are presented in Table 1 in rank order of funds provided.

Instruction projects emphasized comparative studies in the teaching of reading. Special-populations studies emphasized the instruction of handicapped children and of clearly defined ethnic groups. Basic research mainly dealt

TABLE 1

SUMMARY OF READING-RESEARCH SUPPORT FROM THE NATIONAL CENTER FOR EDUCATIONAL RESEARCH AND DEVELOPMENT AND BUREAU OF EDUCATION FOR THE HANDICAPPED*

Category		Amount
Instruction		$ 5,872,358
Special Populations		3,071,835
Basic Research		2,171,747
Language Development		833,634
	Total	$11,949,574

*Adapted from Penney, Hjelm, and Gephart (1970, p. 426).

with various physical phenomena in reading as well as with verbal learning and information processing. Language-development investigations underscored acquisition of different language competencies.

Applied Research: First-Grade Studies

The most ambitious instructionally-oriented research project was the Cooperative Research Program in first-grade reading instruction, summarized by Bond and Dykstra (1967) and by Dykstra (1968). The latter stated one of the main findings of the first-grade studies as follows: "No method was especially effective or ineffective for pupils of high or low readiness as measured by tests of intelligence, auditory discrimination, and letter knowledge [p. 52]."

In discussing the implications of the first-grade studies, Dykstra (1968) noted "that future research should center on teacher and learning characteristics rather than on method and materials [p. 66]."

Basic Research: Project Literacy

The second massive research effort in reading to be supported by USOE was Project Literacy (Levin, Gibson, & Gibson, 1968). The purpose of Project Literacy, coordinated by Harry Levin, Cornell University, from 1963-1968, was to achieve a greater understanding of basic processes of reading through diversified interdisciplinary efforts. Experimental and cognitive psychologists as well as linguists were prominently involved. Key papers resulting from Project

Literacy are presented in Basic Studies on Reading edited by Levin and Williams (1970).

Critique of USOE-Sponsored Research

In summary, it appears that both applied and basic research received massive financial support. The first-grade studies were characterized by:

1. Focus on immediate instructional questions based on atheoretical considerations;
2. Inappropriate experimental design, which did not provide comparability of the results of the 27 studies and made conclusive answers to the practical questions that the studies were intended to answer impossible to obtain.

Project Literacy was based on the conviction that an intensive programmatic research effort emphasizing linguistic, experimental, and cognitive psychology would lead to significant enhancement of basic knowledge of the reading process.

PART 2: RESEARCH AND THEORETICAL LITERATURE: IDENTIFICATION AND ASSESSMENT

Paralleling USOE support in the 1960's for studies in reading were attempts at identifying and assessing the research in the field, especially the emergence of theory and model building. In this part, reviews of research and theory are highlighted to indicate trends and developments. More specific analyses of research and theory are dealt with in the other sections of this report.

Recent Reviews or Syntheses of Research in Reading

ERIC/CRIER, 1966

A major retrieval and dissemination network aimed at collecting and interpreting the extant literature in reading is the USOE-supported Educational Resources Information Center/ Clearinghouse on Retrieval of Information and Evaluation of Reading (ERIC/CRIER). Operational since 1966, ERIC/CRIER is funded through the Bureau of Research in conjunction with the International Reading Association and Indiana University.

As reported by Fay (1971), ERIC/CRIER's objectives are to make available:

> . . . research reports, materials, and information related to all aspects of reading behavior with emphasis on the

2. Although ERIC is charged with interdisciplinary searching and reporting, most of its references bear directly on reading rather than on reading-related subjects from the more basic disciplines.
3. Very few genuinely interpretive papers have been provided by ERIC. Instead, ERIC's publications are typically in the W. S. Gray tradition, giving brief annotated bibliographies under selected headings.

Sixty-Seventh Yearbook, NSSE, 1968

A second major attempt to summarize and interpret research in reading, especially the interpretation of trends and developments of the 1960's, is Innovation and Change in Reading Instruction, the Sixty-Seventh Yearbook of the National Society for the Study of Education, edited by Robinson (1968). In Chapter XI, "The Next Decade," Robinson makes a plea for supporting a greater number of qualified scholars to carry on research in reading. She believes that this step would result in more adequate studies and more vigorous criticism of inadequate studies.

Nine other points are made by Robinson (1968, pp. 416-420):

1. Research workers should be encouraged to explore promising leads without being compelled to draw final conclusions.
2. ERIC/CRIER will minimize duplication of studies.
3. An expanding technology will enhance the minute investigation of sequences and skills.
4. Tremendous computer capabilities, allowing for the sorting and reproduction of isolated, diverse data, promise possibilities for expediting the process of learning to read and of self-diagnosis and prescription.
5. Full-time, scholarly investigators should so raise the quality of research in reading that it will make a difference in the beliefs of the professional.
6. Full-time, scholarly research investigators can provide continuity of effort by pursuing new problems that have arisen from a particular piece of research.
7. A community of scholars with a focus will emerge, inspiring each other as well as supervising younger scholars.
8. Scholars from other disciplines should come together in centers for interdisciplinary research.
9. The results of Items 1-8 should lead to research in reading that is more productive during the next decade "than it has been in any previous one [p. 420]."

Carnegie Report, Chall, 1967

A third recent review and assessment of research on learning to read was made by Chall (1967). In the course of reviewing 67 studies on beginning reading conducted between 1910 and 1965, Chall (pp. 88-93) made four main points that lend support to the observations about the first-grade studies made above by the writer. Chall also made a plea for better research workers, noting that:

1. The questions asked and the answers sought in learning-to-read studies have been inadequate in both depth and scope.
2. Many research studies in reading have lacked a basic rationale as well as continuity.
3. There has been a dearth of synthesizers and theorists in research in reading.
4. The quality of research in reading has suffered because long-term support for highly qualified scholars has not often been provided. Barton and Wilder (1964) and Wilder (1966) have indicated that the average competence of research workers in reading has not been high.

National Advisory Committee on Dyslexia and Related Disorders, 1971

A fourth recent effort at surveying the field of reading with special reference to reading disorders was conducted by the National Advisory Committee on Dyslexia and Related Disorders under the aegis of the National Institute of Neurological Diseases and Stroke. The committee published a collection of 18 papers in a monograph, Reading Forum, edited by Calkins (1971). A few selected papers are highlighted in the remainder of this section. Carroll (1971) cogently pointed out that the "great debate" is really about the order in which reading skills should be taught. The so-called dyslexic child may simply be one who is unable to recognize accurately all of the letters of the alphabet or to break spoken words into their component sounds.

Masland and Cratty (1971) mention three common deficiencies of research work in reading that make it difficult or impossible to evaluate the theories or practical techniques of remedial training:

1. Failure to study representative samples of carefully defined populations;
2. Failure to define a process and a testable hypothesis;
3. Failure to control for unrecognized and independent aspects of remedial programs that are undergoing evaluation. Few research reports have provided detailed documentation of exactly what the training process included.

The inadequacies mentioned by Masland and Cratty are so widespread that we must conclude that most research studies on remedial training in reading are even less adequate than most of those devoted to other aspects of the field.

Proceedings of Conference on Early Experience and Visual Information Processing, 1970

A fifth recent attempt at understanding reading was a conference initially planned by a Committee on Brain Sciences of the National Research Council to bring together three groups of experts:

1. Experimentalists trained mainly as psychologists, neuropsychologists, and neuroanatomists;
2. Practitioners, such as opthalmologists, neurologists, optometrists, and pediatricians who are primarily concerned with examining, diagnosing, and treating children with perceptual and reading disorders;
3. Educators whose major responsibilities in graduate schools of education are training future teachers and conducting research.

Some 58 experts participated and contributed 28 papers to the proceedings of the conference, Early Experience and Visual-Information Processing in Perceptual and Reading Disorders (Young & Lindsley, 1970).

The proceedings are divided into five main sections:

1. Role of the Visual System: Optical and Oculomotor, Retinal, and Central Neural Factors;
2. Attentional and Perceptual Mechanisms;
3. Early Experience and Learning in Visual-Information Processing;
4. The Role of Information Processing in Perceptual and Reading Disabilities;
5. Management of Children with Perceptual and Reading Disabilities.

According to Young and Lindsley, "the goal of the conference was to integrate basic knowledge of the structure and mechanisms of the eye and the brain with their function and their behavioral roles in perception, with the focus on underlying factors that may contribute to reading disorders [p. x]." An examination of the papers of the proceedings revealed several themes that can be summarized as follows:

1. Assessment of and amazement at the visual system and its interface with the brain.

Doty (1970) writes:

> The brain creates the world of visual experience from two million unit-pulsed fibers in the optic nerve and does it by processing this mosaic of digital input into higher-order abstractions that are smoothly continuous in space and time. The manner in which this is accomplished is still so far from adequate scientific explanation that the description "miraculous" is appropriate [p. 143].

2. A development of microcosmic techniques and instrumentation to get at the underlying factors of macrocosmic behavior.

Hirsh (1970), addressing himself to the topic of visual and auditory perception and language learning, reports the spectrographic recording of the speech of children from 3 to 13 years of age and some adults repeating two simple sentences five different times. The two sentences were: "He has a blue pen" and "I am tall." Children showed highly variable speech patterns from ages 3-4 to about ages 11-12. Hirsh (1970) stresses that we cannot speak of speech "habits" having been formed until the preteen period. Hirsh (1970) concludes that "the phoneme is, at best, a very labile model to use for the printed letter [p. 233]."

3. The significance of early growth and development of the visual system and information processing is manifest earlier and earlier as techniques for measurement improve.

Young (1970) in a chapter on the development of optical characteristics for seeing summarizes the literature on the growth of the eye. At birth, the human eye is three-fourths of its adult size. The adult size of the cornea is reached between the first and second years. Fantz's (1970) experiments indicate that newborn infants fixate some objects and patterns for longer periods than others. A study done by Miranda (1969) shows that even premature infants can see patterned stimulation.

A glossary of 225 terms abounds with examples of the differentiating terminology symptomatic of refinements of the tools, techniques, and concepts used by these research workers.

Summary and Conclusions About Research on Reading

What appears to be emerging from this review of five major reviews of reading research is that interest, effort, and support for reading research have been shifting from a

practical level to a more detailed basic interdisciplinary thrust. In essence, reading research has been moving away from "little science" to "big science." Big science is typically more mission-oriented than little science, bringing together men of diverse backgrounds to tackle projects beyond the capabilities of an individual. Greenberg (1967) summarizes the distinctions between big science and little science:

> Big science is expensive science, involving large teams of scientists and technicians working with greater facilities. . . . Little science, on the other hand, involves fewer people per project and far less costly equipment, the extreme in this category being the lone theoretical mathematician whose tools are paper and pencil. In substance, science, big or little, is science, and there is as yet no rational method for correlating the cost of research and its intellectual worth or ultimate utility. But the economics of big and little science are strikingly different and, inevitably, so are the products [p. 11].

Perhaps the Zeitgeist demanding more social relevance on the part of the basic disciplines in combination with the inadequacies of research in reading during the past 60 years has accelerated the thrust toward serious reappraisal and the movement toward basic research and theory building during the past decade.

Reading Theory and Models

The aim of this part of the paper on reading theories and models is similar to the preceding review of research on reading; namely, to highlight and give historical perspective to the key literature on theories and models of reading. Of interest here is that the efforts at theories and model building in reading have been identified with "little-science" efforts of a few dedicated individual scholars working together with their graduate students with very little substantive support. Hence, theories or models, or both, tend to emphasize individual points of view which draw attention to variables, symbols, rules, processes, analogies, and explanations as to the how and why of reading. Five major references were identified along with the models given in each source. Some perspectives are presented at the end of this part.

Holmes-Singer Review, 1964

Holmes and Singer (1964) provided one of the first wide-ranging assessments of the theoretical models extant in 1963. Six explicitly formulated models cited were: (a) Teaching Machines; (b) Synaptic Transmission; (c) Mixed Dominance;

(d) Initial Teaching Alphabet (ITA); (e) Substrata-Factor Theory; (f) Structural Linguistics (Fries).

Three of the models (b, c, and e) emphasize intraindividual variables; two of them (d and f) stress linguistics; one (a) stems from operant conditioning. The earliest explicit theory is the Substrata-Factor Theory, first presented in 1948.

Holmes and Singer (1964) note:

> . . . at least three new and exciting trends are clearly discernible: (a) a concerted effort at theory building, (b) a greater concern for designs that are experimentally and statistically sophisticated, and (c) a host of new instruments and techniques.
>
> A field of study is generally headed for a spurt of creative productivity when theory construction and experimental research became closely interdependent and mutually directed. All signs indicate that the psychology of reading is on the threshold of just such a forward thrust and that both stimulating and disturbing days lie immediately ahead. In this new atmosphere, cherished ideas are found to be challenged, and new ones will contend for their places when the old ones fall [p. 150].

Symposium on the Use of Theoretical Models in Research, International Reading Association, 1966

Kingston (1966) organized a symposium for the International Reading Association in 1965 which contributed further toward interest in theory. Three major papers were presented:

1. The Model in Theorizing Research by Elizabeth Maccia, a philosopher-scientist;
2. Integrated-Functional Theory and Reading by Arthur Staats, a psychologist who has made use of operant conditioning techniques;
3. General Open Systems Theory and the Substrata Factor Theory of Reading by Martin Kling, an experimental and educational psychologist.

Kingston (1966) described the papers presented at the symposium as "a pioneer attempt to explore the concept of model with a view toward examining some of the possibilities of using theoretical models in reading research [p. 3]."

Clymer's Review, NSSE, 1968

In addition to Holmes's Substrata Factor Theory and Smith and Carrigan's Synaptic Transmission Model, Clymer

(1968) described five taxonomic attempts to construct models of the reading process:

1. Strang's classification: products, prerequisites, the reading process, and procedures;
2. Spache's extension of Guilford's structure-of-the intellect model;
3. McCullough's schema of thought patterns;
4. Barrett's taxonomy of the cognitive and affective dimensions of reading comprehension;
5. Gray-Robinson's model, emphasizing rates, word perception, comprehension, reaction to author's ideas, and assimilation of what is read.

Theoretical Models and Processes of Reading, International Reading Association, 1970

This collection of papers on theoretical models, edited by Singer and Ruddell (1970), presented several models that had not previously appeared in reviews. Five main types of models were presented:

Linguistics (Reed, 1965)
Psycholinguistics (Goodman, 1967; Ruddell, 1970)
Information Processing (Geyer, 1970; Venezky & Calfee, 1970)
Cognitive Processes (Hochberg & Brooks, 1970)
Perception (Gibson, 1965; Samuels, 1970)

Perspectives

Systematic theory building in reading essentially began in 1948 with Holmes's Substrata-Factor Theory and gained momentum in the late 1950's. While most of the earlier theories tended to rest largely on the observation and psychology of reading, theoretical formulations of the middle and late sixties emphasized concepts drawn from linguistics, psycholinguistics, and cognitive psychology. A total of 20 models have been identified in the reviews. It is interesting to note that those who do research are often in communication with those who build models or are, indeed, the same people.

PART 3: RATIONALE AND OBJECTIVES OF THE LITERATURE SEARCH

Rationale

The rationale of the Literature Search in Reading reported in this volume is predicated on two fundamental

assumptions of the Targeted Research and Development Program on Reading (TRDPR) as delineated by Penney, Hjelm, and Gephart (1970):

> 1. . . . systematic efforts in model development and in instructional-system development can speed progress towards the attainment of functional reading competence by all learners [p. 436];
>
> 2. . . . continued application of the convergence-technique management procedures should, in fact, make work on model and instructional-system development more systematic and efficient than it has been in the past [pp. 436-438].

The five phases envisaged by Gephart (1970) for the targeted Research and Development Program on Reading are presented in his Figure 1 (1970, p. 510). The concern of the Literature Search is with Phase 1, the Preresearch Component. The remaining four phases envisaged by Gephart were: Instructional-system component research and development; system assembly and test; delivery-system development; and implementation.

Objectives of the Literature Search

The primary objectives of the literature search outlined by Kling, Geyer, and Davis (1970) were to:

1. Identify and evaluate all significant contributions to literature in: (a) language development related to reading; (b) learning to read; (c) the reading process;
2. Identify in the literature explanations of how processes operate and how the behavioral events or operations within them interact with one another (in short, to identify or build comprehensive or partial models of these processes);
3. Describe and synthesize models in order to present as many different logically coherent models in each of the areas (or in any combination of the three) as seem necessary to exhaust the insights and evidence available;
4. Describe the hypotheses and tests central to developing new research studies, to refine and extend the models presented, to test the assumptions on which they were based, and to synthesize with them the unincorporated facts and insights of the fields studied.

Concept of an Invisible College

The general organizational basis underlining the implementation of the objectives of the literature search

was the development of an "Invisible College" (Price, 1963). According to Price and Beaver (1966), the term "Invisible College" was applied to a group of people who met informally in the midseventeenth century and later organized into the Royal Society of London. Members of an invisible college characteristically: (a) keep in touch with everyone else who is doing research in a given subject nationally or internationally: (b) travel frequently between one center and another; (c) circulate preprints and reprints to each other; (d) collaborate in research; (e) meet with each other at conferences; (f) decide, intentionally or unintentionally, on a general strategy to attack a given area.

An Invisible College of Basic Research on Reading

Kling (1971) identified several characteristics of an invisible college that would be needed if it was to carry out the four main objectives of a literature search.* These follow:

1. It should include a team of scholarly reviewer-evaluators
   a. These scholars should represent a variety of disciplines;
   b. These scholars should represent various theoretical and research points of view;
   c. These scholars should be active research workers in their given disciplines who are interested in reading;
   d. These scholars should demonstrate interest and creative effort in model building;
   e. These scholars should be involved in ongoing training programs.
2. It should include an Advisory Panel whose members should have characteristics comparable with those of the reviewer-evaluators.
3. It should include a Central Processing Group (CPG) to coordinate and facilitate the activities of the reviewer evaluators.
   a. Members of the CPG should have characteristics comparable with those of the reviewer evaluators;
   b. Computer facilities (programs, programmers, and hardware) should be made available.

---

*During the weekend of April 10, 1970, Drs. Athey, Geyer, Kling, and Singer met at Rutgers to examine the prerequisites and nature of a literature search. The heart of the proposal subsequently submitted was based on the seminal thinking of that meeting. A few weeks later, Dr. Davis joined the TRDPR proposal-writing team of Geyer and Kling.

4. It should encourage interchange between reviewer-evaluators, Advisory-Panel members, and the Central Processing Group.
5. It should make arrangements for reports to be presented at professional meetings.

The Organization of the Literature-Search Team

Reviewer evaluators, Advisory-Panel members, and the Central Processing Group covered three areas: (a) Language Development; (b) Learning to Read; and (c) Reading Process. Within each area, a scholar was responsible for a specific domain.

In the Language-Development area, the following participated as reviewer-evaluators: Irene J. Athey, University of Rochester, "Language Models and Reading"; Doris R. Entwisle, The Johns Hopkins University, "Implications of Language Socialization for Reading Models and for Learning to Read"; and Ronald Wardhaugh, University of Michigan, "Theories of Language Acquisition in Relation to Beginning Reading Instruction." The Advisory-Panel members were: David Elkind, University of Rochester; Richard E. Hodges, University of Chicago; and Robert B. Ruddell, University of California, Berkeley.

In the Learning-to-Read area, the following participated as reviewer-evaluators: Richard D. Bloom, State University of New York at Stony Brook, "Learning to Read: An Operant Perspective"; William B. Gillooly, Rutgers University, "The Influence of Writing-System Characteristics on Learning to Read"; Duncan N. Hansen, Florida State University, "Information-Processing Models for Reading-Skill Acquisition"; and Joanna P. Williams, University of Pennsylvania, "Learning to Read: A Review of Theories and Models." The Advisory-Panel members included James S. Deese, The Johns Hopkins University; S. Jay Samuels,* University of Minnesota; and Harry Singer,† University of California, Riverside.

In the Reading-Process area, the following participated as reviewer-evaluators: Frederick B. Davis, University of Pennsylvania, "Psychometric Research on Comprehension in Reading"; Jane F. Mackworth, Stanford University, "Some Models of the Reading Process: Learners and Skilled Readers"; Norman H. Mackworth, Stanford University, "Seven Cognitive Skills in

---

*Also contributed a paper entitled "Success and Failure in Learning to Read: A Critique of the Research."

†Also contributed a paper entitled "Theories, Models, and Strategies for Learning to Read."

Reading"; H. R. Schiffman, Rutgers University, "Sensory and Perceptual Aspects of the Reading Process"; Stanley F. Wanat, Stanford University, "Linguistic Structure in Reading: Models from the Research of Project Literacy"; and Wendell W. Weaver, University of Georgia, "Modeling the Effects of Oral Language Upon Reading Language." The Reading-Process Advisory-Panel members were Robert Efron, V. A. Hospital, Martinez, California; Albert J. Kingston,* University of Georgia; Paul A. Kolers, University of Toronto; and Karl H. Pribram, Stanford University.

The Central Processing Group, located at Rutgers, consisted of Martin Kling, Rutgers University, Principal Investigator; Frederick B. Davis, University of Pennsylvania, Director; John J. Geyer, Rutgers University, Associate Director and Coordinator of the Reading-Process area; Irene J. Athey, University of Rochester, Coordinator of the Language-Development area; and Joanna P. Williams, University of Pennsylvania, Coordinator of the Learning-to-Read area.

Frederick B. Davis and Martin Kling provided liaison with Project 1 at Educational Testing Service, Princeton, New Jersey. Project 1 called for identifying the functional reading tasks of adults in order to establish a base for constructing criterion tests. James Kimple, Superintendent of Schools, South Brunswick, and Martin Kling provided liaison with Project 3, a literature search of the present status of teaching and the outcomes of reading conducted at the office of the Educational Testing Service in Berkeley, California.

PART 4: STRATEGIES AND MILESTONES OF THE LITERATURE SEARCH

Milestone 1: The Working Bibliography

The basic stance assumed for assembly of the working bibliography might be described as sophisticated naiveté; that is, leaving no stone unturned in an effort to identify the extant literature in all of the three areas. In order to facilitate the attainment of objectives, the reviewer-evaluators and Advisory-Panel members submitted working bibliographies in the domains for which they were responsible. A total of 8,544 references were obtained in this manner after duplicates had been eliminated. Table 2 summarizes the number and percent of references according to areas. It shows that twice as many references were submitted in the Reading-Process area as in the other two areas and that the Learning-to-Read area and the Language-Development area each accounted for about a

---

*Also contributed a paper entitled "Disjunctive Categories in Ephemeral Models" and co-authored with Wendell W. Weaver a paper entitled "Modeling the Effects of Oral Language Upon Reading Language."

TABLE 2

NUMBER AND PERCENTAGE OF REFERENCES IN THE WORKING BIBLIOGRAPHY, CLASSIFIED BY AREA

Area		Frequency	Percent of total
Language Development		1,868	22
Learning to Read		2,225	26
Reading Process		4,451	52
	Total	8,544	100

quarter of the total. All references were put on magnetic tape in the format of a retrieval program, TEXT-PAC, initially developed by IBM and modified for use with the IBM 360/67. The following printouts of the working bibliography can be obtained:

1. Accession-Number Index. This listing consists of the references arranged by numerical order of their six-digit accession numbers.
2. Author Index. This listing consists of the references arranged by alphabetical order of the author's (or principal author's) last name.
3. KWOK (Key Word Out of Context) Index. This listing consists of an alphabetical arrangement of key words in the titles of the references.
4. Primary- and Secondary-Category Index. This listing consists of an alphabetical arrangement of descriptors assigned by reviewer-evaluators to the references. If desired, the listing can be restricted to references judged by the reviewer-evaluators to be of primary importance in connection with each descriptor or to be of secondary importance in connection with each descriptor.
5. Frequency Word Index. An alphabetical listing of all words and all references with the number of times each word appeared and the number of references containing it. The words in this output could be used to develop a thesaurus or to aid in deleting irrelevant descriptors, such as predicates.

These indices were updated four times during the year. They were mailed to the members of the TRDPR Literature-Search group and discussed by them at the three conferences held at Rutgers University. In addition, master tapes were developed for each of these outputs. The working bibliography served to define a given domain and area and facilitated the subsequent sifting of references for further analysis.

Milestone 2: Development and Use of a Reference Evaluation Form

Under the leadership of Jason Millman, Professor of Educational Research Methodology, Cornell University, a Reference Evaluation Form (REF) was developed. Five reference categories were set up: Model, Research, Non-research, Model and Research, and Model and Non-research.

If a reference presented a model, the following items were included:

1. An abstract of the reference;
2. A statement of the assumptions of the author or authors;
3. A classification of the model as didactic or generative;
4. A classification of the model as comprehensive or partial;
5. A classification of the model by type (example, analogy, isomorph);
6. A classification of the model by orientation (education, information processing, linguistics, mathematics-statistics, neurology, psychology, sociology);
7. Constituent elements (the variables and their interactions).

If a reference presented research findings, the following responses were requested of the reviewer-evaluators:

1. An abstract of the reference;
2. A statement of the assumptions of the author or authors;
3. Identification of the main thrust of the reference;
4. Description of the research design (treatments, instruments, analysis);
5. A list of stated but untested hypotheses;
6. A list of weak conclusions;
7. A list of the strong conclusions drawn by the author;
8. A list of the strong conclusions drawn by the reviewer.

If a reference was categorized as non-research, the reviewer evaluators were asked to provide:

1. An abstract of the reference;
2. A statement of the assumptions;
3. A list of untested hypotheses.

The main purpose of the Reference Evaluation Form was to assess those references that warranted further critical

review. The basic strategy adopted by the TRDPR team was first to identify and assess models and then to seek out related research. Often non-research references were read first since these articles were mainly reviews of a given field.

Milestone 3: Computerization of Reference Evaluation Forms by Interrogation Criteria

A program was developed to retrieve each of the five categories of REF's as well as specific sections. For example, printouts of all models in a given area along with constituent elements can be retrieved and listed. In order to gain some knowledge about the recency of the 860 REF's prepared, a sort was made according to source and year for a given area. Of these 671, or 78 percent, were based on journal articles. Half of these 671 articles were published after 1967. Of the 123 journals including the 860 references for which REF's were prepared, 47 were in the field of psychology. They accounted for 50 percent of the references. The 18 journals that included one percent or more of the references are listed in Table 3. This table shows that:

1. A very small number of journals account for over half of the REF's;
2. A majority of the articles are in journals of experimental and educational psychology;
3. A majority of the journals stress theory and research;
4. Three journals are primarily in the field of reading and account for 7.6 percent of the REF's;
5. One journal, Cognitive Psychology, founded in 1970, accounts for 1 percent of the REF's.

Milestone 4: Evaluative Survey Papers

In addition to compiling the working bibliography and preparing the Reference Evaluation Forms, the reviewer-evaluators wrote critical surveys of the research literature. Three panel members also wrote papers of this type. Preliminary versions of these were reviewed by Advisory-Panel members; many of them were discussed at group meetings and presented at the following professional conventions:

National Reading Conference, St. Petersburg, Florida; December 3-5, 1970
(one symposium; attendance, 200)

American Educational Research Association, New York, New York; February 4-6, 1971
(six symposia; attendance, 600)

TABLE 3

JOURNALS CONTRIBUTING 1 PERCENT OR MORE OF 671 REFERENCE EVALUATION FORMS FOR LANGUAGE-DEVELOPMENT, LEARNING-TO-READ, AND READING-PROCESS AREAS

Rank	Journal	Frequency	Percent
1.	Journal of Verbal Learning and Learning Behavior	73	11.0
2.	Journal of Experimental Psychology	44	6.6
3.	Child Development	37	5.5
4.	Perception and Psychophysics	35	5.2
5.	Journal of Educational Psychology	27	4.0
6.	Psychological Review	25	3.7
7.	The Reading Teacher	19	2.8
8.	Elementary English	16	2.4
9.	Reading Research Quarterly	16	2.4
10.	Perceptual and Motor Skills	15	2.2
11.	Science	12	1.8
12.	Language and Speech	11	1.6
13.	Psychonomic Science	11	1.6
14.	American Educational Research Journal	8	1.2
15.	American Journal of Psychology	8	1.2
16.	Journal of Experimental Child Psychology	8	1.2
17.	Cognitive Psychology	7	1.0
18.	Journal of Speech and Hearing Disorders	7	1.0
	Total	379	56.4

International Reading Association, Atlantic City, New Jersey; April 19-20, 1971
(two-day preconvention institute; attendance, 250)

American Psychological Association, Washington, D.C.; September 3-7, 1971
(two symposia and one paper)

Plans have been completed for the Evaluative Survey papers and certain summary sections of this report to be published in the Reading Research Quarterly. The first segment, the Background and Development of the Literature Search and Language Development and Reading, will appear in the Fall 1971 issue. The second segment, on Learning to Read, and the third segment, on the Reading Process, will appear in the two succeeding issues.

REFERENCES

Barton, A. H., & Wilder, D. E. Research and practice in the teaching of reading: A progress report. In M. B. Miles (Ed.), Innovation in education. New York: Bureau of Publications, Teachers College, Columbia University, 1964. Pp. 361-398.

Bond, G. L., & Dykstra, R. The Cooperative Research Program in first-grade reading instruction. Reading Research Quarterly, 1967, 2, 5-141.

Calkins, E. O. (Ed.) Reading forum. Washington, D.C.: U.S. Government Printing Office, 1971.

Carroll, J. B. The nature of the reading process. In E. O. Calkins (Ed.), Reading forum. Washington, D.C.: U.S. Government Printing Office, 1971. Pp. 1-10.

Chall, J. S. Learning to read: The great debate. New York: McGraw-Hill, 1967.

Clymer, T. W. What is "reading"?: Some current concepts. In H. W. Robinson (Ed.), Innovation and change in reading instruction. Chicago: National Society for the Study of Education, 1968. Pp. 7-29.

Doty, R. W. Modulation of visual input by brain-stem systems. In F. A. Young & D. B. Lindsley (Eds.), Early experience and visual information processing in perceptual and reading disorders. Washington, D.C.: National Academy of Sciences, 1970. Pp. 143-150.

Dykstra, R. Summary of the second-grade phase of the Cooperative Research Program in primary reading instruction. Reading Research Quarterly, 1968, 4, 49-70.

Fantz, R. L. Visual perception and experience in infancy: Issues and approaches. In F. A. Young & D. B. Lindsley (Eds.), Early experience in visual information processing in perceptual and reading disorders. Washington, D.C.: National Academy of Sciences, 1970. Pp. 351-381.

Fay, L., Bradtmueller, W. J., & Summers, E. G. Doctoral studies in reading 1919 through 1960. Bloomington: Indiana University Press, 1964.

Fay, L. Reading research: Methodology, summaries, and application. Newark, Del.: International Reading Association, 1971.

Gephart, W. J. The targeted research and development program on reading: A report on the application of the convergence technique. Reading Research Quarterly, 1970, 5, 505-523.

Geyer, J. J. Models of perceptual processes in reading. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 47-94.

Gibson, E. J. Learning to read. Science, 1965, 148, 1066-1072.

Goodman, K. S. Reading: A psycholinguistic guessing game. Journal of the Reading Specialist, 1967, 4, 126-135.

Greenberg, D. S. The politics of pure science. New York: New American Library, 1967.

Hirsh, I. J. Visual and auditory perception and language learning. In F. A. Young & D. B. Lindsley (Eds.), Early experience and visual information processing in perceptual and reading disorders. Washington, D.C.: National Academy of Sciences, 1970. Pp. 231-245.

Hochberg, J., & Brooks, V. Reading as an intentional behavior. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 304-314.

Holmes, J. A., & Singer, H. Theoretical models and trends toward more basic research in reading. Review of Educational Research, 1964, 34, 127-155.

Kingston, A. J. (Ed.) Use of theoretical models in research. Newark, Del.: International Reading Association, 1966.

Kling, M. Developing a data base for model building in reading. In F. P. Greene (Ed.), Twentieth yearbook of the National Reading Conference. Milwaukee: The National Reading Conference, 1971, in press.

Kling, M., Geyer, J. J., & Davis, F. B. Proposal for TRDPR Project No. 2, Literature Search. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1970.

Levin, H., Gibson, E. J., & Gibson, J. J. The analysis of reading skill: A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968.

Levin, H., & Williams, J. P. (Eds.) Basic studies on reading. New York: Basic Books, 1970.

Masland, R. L., & Cratty, B. J. The nature of the reading process, the rationale of noneducational remedial methods. In E. O. Calkins (Ed.), Reading forum. Washington, D.C.: U.S. Government Printing Office, 1971. Pp. 141-166.

Miranda, S. B. Visual abilities and pattern preferences of premature infants and full-term neonates. Unpublished manuscript, Case Western Reserve University, 1969.

Penney, M., Hjelm, H. F., & Gephart, W. J. The targeted research and development program on reading. American Educational Research Journal, 1970, 7, 425-448.

Price, D. J. de S. Little science, big science. New York: Columbia University Press, 1963.

Price, D. J. de S., & Beaver, D. de B. Collaboration in an invisible college. American Psychologist, 1966, 21, 1011-1018.

Reed, D. W. A theory of language speech and writing. In L. Courtney (Ed.), Linguistics and reading. Newark, Del.: International Reading Association, 1966. Pp. 4-25.

Robinson, H. B. (Ed.) Innovation and change in reading instruction. Chicago: National Society for the Study of Education, 1968.

Ruddell, R. B. Language acquisition and the reading process. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 1-19.

Samuels, S. J. Modes of word recognition. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 23-37.

Singer, H., & Ruddell, R. B. (Eds.) Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970.

Summers, E. G. Recent doctoral dissertation research in reading. Bloomington, Ind.: ERIC Clearinghouse on Reading, 1967. Microfiche No. ED016603.

Summers, E. G. Reading research literature: Identification and retrieval. Reading Research Quarterly, 1968, 4, 5-48.

Venezky, R. L., & Calfee, R. C. The reading competency model. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 273-291.

Wilder, D. E. The reading experts: A case study of the failure to institutionalize an applied science of education. Unpublished doctoral dissertation, Columbia University, 1966.

Young, F. A. Development of optical characteristics for seeing. In F. A. Young & D. B. Lindsley (Eds.), Early experience and visual information processing in perceptual and reading disorders. Washington, D.C.: National Academy of Sciences, 1970. Pp. 35-61.

Young, F. A., & Lindsley, D. B. (Eds.) Early experience and visual processing in perceptual and reading disorders. Washington, D.C.: National Academy of Sciences, 1970.

SECTION 2

QUEST FOR SYNTHESIS

Martin Kling

Rutgers University

INTRODUCTION

This section seeks to provide some measure of integration, some sense of unity among the three areas: Language Development, Learning to Read, and the Reading Process. It is based on (a) scrutiny of the working bibliography of the literature of research in reading, which includes 8,544 items; (b) study of the 860 articles judged by the reviewer-evaluators to be sufficiently important to be analyzed in detail and summarized on Reference Evaluation Forms; and (c) careful reading of the papers that make up sections 3 through 8 of this report. The emphasis in this section is on models of reading and needed research.

Over 100 of these models were found in the literature search.* In approach, they range from behavioristic (Staats, 1968) to nativistic or biological (Lenneberg, 1967).

THE ROLE OF MODELS IN RESEARCH

Some research workers maintain that premature theory formulation or model building may foreclose further inquiry. Stogdill (1970) noted that these workers prefer to gather and analyze data on a trial-and-error basis until hypotheses emerge that fit the data. Other workers first formulate a hypothesis and then gather data deliberately planned to test it--i.e., data that will either confirm or discredit it. If the latter, they use the data to reformulate the hypothesis and repeat the process. This method of attack has considerable logical appeal. As Stogdill (1970) stated:

---

*The writer is in accord with Stogdill's (1970, p. 11) conception of a model. The term "model" is less pretentious than "theory" and implies a somewhat shorter lifespan. Nevertheless, a model exhibits all the logical, empirical characteristics of a theory.

> If data from repeated measurements on a system fail to fit a given model, common sense dictates the development of a better model as a guide to further research. After all, the only knowledge we have in science is that which comes to us in the form of a model or theory, whether or not it is labeled as such [p. 10].

Chapanis (1963) has listed some of the dangers and rewards of model building. Among the dangers are:

1. Models invite overgeneralization;
2. Models may lead us into logical fallacies;
3. Models may display relationships among variables that may be incorrect;
4. Models may assume constants that are incorrect;
5. Models are often not validated;
6. Model building may divert potentially useful energy into nonproductive activity [pp. 122-127].

On the positive side, models

1. Describe and help us understand complex systems;
2. Help us learn complex skills;
3. Help us see new relationships;
4. Provide the framework for experimentation;
5. May indicate areas in which experimentation is not possible;
6. Assist in engineering design;
7. May amuse us [pp. 113-121].

Both the dangers and the useful functions of model building are manifest in the models described in sections 3-8 of this report. In evaluating models used in reading research, Kingston (1971) called attention to the incongruity between most of them and reality. Yet, if research is to have a proper theoretical base, a model--that is, a working hypothesis--is required. Kuhn (1970, p. 15) pointed out that in the absence of models ". . . all the facts that could possibly pertain to the development of a given science are likely to seem equally relevant."

Perhaps the most striking generalization that emerges from the literature is that research in reading has been shifting rapidly during the last five years from an atheoretical to a theoretical base with concomitant interest in developing models of reading and more nearly adequate definitions of it.

READING AS AN INTERDISCIPLINARY MATRIX

The models described in the following sections of this report are supported by arguments and data drawn from five disciplines: psychology, psycholinguistics, information processing, sociolinguistics, and the biobehavioral sciences.

Psychology

Reading models derive from several areas of psychological investigation: perceptual-conceptual (Gibson, 1970); behavioristic (Staats & Staats, 1962); nativistic (Lenneberg, 1967; McNeill, 1970); cognitive (Bruner, Goodnow, & Austin, 1966; Elkind, 1967, 1970; Gagné, 1966; Neisser, 1967; Piaget, 1970; Williams, 1971); and psychometrics (Davis, 1971).

Psycholinguistics

According to Goodman (1969), this discipline has contributed three kinds of information:

1. Grapho-phonic information from the graphic and phonological systems of oral and written language and their relationships (Chomsky & Halle, 1968);
2. Syntactic information implicit in the grammatical structures of the language (Chomsky, 1965);
3. Semantic information that involves strategies in obtaining meaning (Creelman, 1966; Deese, 1969; Katz & Postal, 1964; Laffal, 1965; McNeill, 1970; Osgood, 1968; Ruddell, 1970).

Information Processing

Information processing has relied heavily on cybernetics, which "covers the entire field of control and communication in the machine and in the animal [Lionnais, 1966, p. 60]." In this report, models drawing on this discipline are described in the evaluative survey papers by Athey (1971) and Hansen (1971) and the coordinating paper by Geyer (1971). These papers deal, respectively, with models in language development, learning to read, and the reading process.

Sociolinguistics

Sociolinguistics has provided a framework of group differences that have often been ignored in reading models. These include differences in dialect, differences among ethnic groups in information-processing skills, differences in cognitive style, and differences arising from affective factors. According to Entwisle (1971), there is a genuine need for the development of sociolinguistic theory.

Biobehavioral Sciences

Neurobehavioral and psychophysiological theorizing and research by Bagshaw and Benzies (1968), Pribram (1954, 1963,

1966, 1969), and Sokolov (1969) and ethology as presented by Lorenz (1969) help explain how people learn and remember. For example, in reviewing Hydén's (1969) chapter "Biochemical Aspects of Learning and Memory" in On the Biology of Learning (Pribram, 1969), Pribram notes the possibility of common substrata linking inheritance and learning. The mechanisms of inheritance involve molecules made up of "deoxyribonucleic acids (DNA), which, by way of ribonucleic acids (RNA) instruct (that is, give structure to) the proteins and other large molecules that make up the substance of our bodies [p. 4]." Pribram underscores the significance of Hydén's discovery that large amounts of RNA are secreted by the nerve cells under stimulation. This finding contrasts sharply with the view previously held that nervous tissue was metabolically relatively inert. The work of the biobehavioral scientists should do much eventually to modify some of the extreme positions taken by those holding the behavioristic and nativistic points of view highlighted in the language-development area by Athey (1971) and Wardhaugh (1971).

The paper by Geyer (1971) presents five neurological models that bear on phenomena related to the reading process. Jane Mackworth (1971) incorporates most of the macromolecular parts of the reading process into a comprehensive model. A program of experiments for investigating the subsystems in this model has been proposed by Norman Mackworth (1971).

TOWARD CONVERGENCE OF DIVERGENT MODELS

There seems to be a tendency toward reconciling the differences between the models proposed to explain the nature of reading. Behaviorists, for example, are modifying the familiar S-R paradigm of learning to include the cognitive functions found in the S-O-R paradigm (Bloom, 1971; Staats, Brewer, & Gross, 1970). Other differences will tend to disappear as changes occur in terminology and level of knowledge in the underlying disciplines, in the type of measurement and analysis employed, and in the methodology used.

Some Basic Generalizations About Reading

The Need to Reduce Uncertainty

From birth on, an organism needs to reduce uncertainty, or to gain information (Fantz, 1970; Hochberg & Brooks, 1970; Roberts & Lunzer, 1968; Smith, 1970; Wanat, 1971).

> If we regard reading [as] like any other process of acquiring information, [which tends to reduce] uncertainty, then we have discovered the first way in which the conventionally disparate areas of letter identification, word identification, and "reading for comprehension" can be considered

> in the same light. In each of the three aspects of reading, information is acquired visually to reduce a number of alternative possibilities [Smith, 1970, p. 18].

The Importance of Distinctive Features

How to recognize distinctive features, or identify the uniquely critical properties of an object, was studied by Gagné and Gibson for the Army Air Forces in 1944. The task was to identify forty different types of airplanes. Gibson (1969) described the results as follows:

> The best results were secured by teaching distinctive features such as a tapered wing, a short nose, or a beer-bottle fuselage. There was a unique cluster of such features for each plane. It was not necessary that a full description or picture of each be memorized, but only that the feature pattern making it different from the others be detected. It was in fact concluded that no features should be emphasized unless they served to distinguish one plane from another [p. 83].

The distinctive features of phonemes were delineated by Jakobson and Halle (1956), and their findings were supported experimentally by Brown and Hildum (1956). Improvement of differentiation within phoneme pairs was noted by Scvachkin (Tikofsky & McInish, 1968). Discrimination is learned earliest for pairs that have the largest number of distinctive features.

The distinctive features of graphemes were identified by Gibson, Osser, Schiff, and Smith (1963). Samuels (1971) reviewed most of the studies about distinctive features, and Schiffman (1971) assessed some of the sensory processes involved in using distinctive features in reading.

Neurophysiological support for the value of distinctive features in differentiation comes from studies of the frog, whose retinal cells are adapted for detecting bugs (Lettvin, Maturana, McCulloch, & Pitts, 1959), the cat (Hubel & Wiesel, 1959) and the monkey (Hubel & Wiesel, 1968; Wiesel & Hubel, 1966). Detectors of more general features have been found in the human cortex (Weisstein, 1969).

Internal Representation

The organism internalizes a representation, called a schema by Bartlett (1932), a plan by Miller, Galanter, and Pribram (1960), and a working system by Holmes (1960). This essentially means that the organism is developing a hierarchy that controls the order in which a sequence of operations takes place.

Early and Rapid Development of Language

There is general agreement that a child's ability to use the more common grammatical patterns of speech is pretty well developed by the time he is 3 to 3-1/2 years old (Bellugi & Brown, 1964). From 3-1/2 to 5 years of age, he learns the more complex patterns. However, investigators disagree as to how to interpret these findings (Athey, 1971; Wardhaugh, 1971).

Reader Expectation and Confirmation-Disconfirmation

Levin and Kaplan (1970) have suggested that

> . . . the reader, or listener, continually assigns tentative interpretations to a text or message and checks these interpretations. As the material is grammatically or semantically constrained he is able to formulate correct hypotheses about what will come next. When the prediction is confirmed, the material covered by that prediction can be more easily processed and understood. This model of reading, that is, of understanding written material, is in its important aspects applicable also to spoken language [p. 132].

The Levin-Kaplan view of hypothesis formation and confirmation-disconfirmation is similar to Goodman's (1970).

> The reader . . . predicts and anticipates on the basis of [syntactic and semantic] information, sampling from the print just enough to confirm his guess of what is coming, to cue more semantic and syntactic information. Redundancy and sequential constraints in language, which the reader reacts to, make this prediction possible [p. 266].

Some Basic Areas of Agreement or Emphasis

Rapproachement Between Language Development, Learning to Read, and the Reading Process

Role of cognition. All 16 papers in this report show the influence of cognitive psychology. This influence has led not only to modifications of operant-learning theory (Bloom, 1971) and of associative-learning theory (Samuels, 1971) but also to a different understanding of our orthographic system, which is not, according to Gillooly (1971), a "one-sound, one-symbol system" but has characteristics more in keeping with Chomsky's levels of lexical abstraction.

Speaking and reading. Jane Mackworth (1971), drawing on the work of Liberman, Cooper, Shankweiler, and Studdert-Kennedy (1967), noted that a person's identification of words

depends on ". . . a three-way synthesis between certain sounds, both that he makes, and those others make, feedback from his speech motor system, . . . and meaning [p. 8-69]." At the reading level "there is again a three-way synthesis between the spatial signs, the spoken word, and meaning. Again, there is a parallel processing of input, this time visual, followed by the sequential verbal processing [p. 8-70]."

The Liberman model of speech perception is further described by Geyer (1971). Also, some difficult issues in the relationship between oral language and reading are raised by Weaver and Kingston (1971).

Rapproachement Among Models of Language Development, Learning to Read, and the Reading Process

Samuels (1971) has attempted to identify the hierarchy of skills required in learning to read and has presented experimental evidence to support his conclusions. Although many of the studies cited by Samuels are different from those cited by Jane Mackworth (1971), the subsystems specified by Samuels and incorporated into his associative learning paradigm are similar to those in Jane Mackworth's model. Samuels' paradigm is concerned with attentional processes, learning distinctive features of visual stimuli ("matching input with a memory trace," according to Mackworth), visual-information store, short-term memory, and long-term memory. Samuels' mediation or hookup between auditory and visual stimuli is essentially Jane Mackworth's coding process. In addition, Menyuk (1970) has outlined a macro-language model including a filtering mechanism, short-term memory and production strategies, long-term memory, and the grammar of language.

Rapproachement Between Computer Simulation Models and Human Beings

Hunt (1971) has attempted a theoretical integration of the analogy between human beings and computing systems. His comprehensive distributed-memory model draws upon theoretical analyses in both psychology and computer science. This model has as its central component a long-term memory (LTM) with a hierarchy of peripheral, temporary memories (or buffers) surrounding it. Recognizing that the visual system alone can transmit data at the rate of 4.3 10^6 bits per second and that silent reading typically proceeds at 45 bits per second, Hunt reasoned that if a human being is going to control his environment, he must have a peripheral device to screen important information and "provide the central computer with an orderly queue of data [p. 60]."

Beginning with a sensory buffer consisting of a transducing mechanism, a memory register, and a feature-detection

unit, Hunt proceeded to make isomorphic points of comparison in a hierarchical development of intermediate buffers and higher-order recognition, parsing and feedback, errors that a hypothetical human computing system would make, task interruption, learning, verbal comprehension, problem solving, and concept identification. Hansen (1971) extended the computer analogy to the development of computer-assisted instruction (CAI) for learning to read and the reading process.

LEVEL OF MODEL DEVELOPMENT

Luce (1970) provided a useful outline for thinking about the level of model development. Although he emphasized that the categories are not exhaustive, hierarchical, mutually exclusive, or sharply defined, his classification accommodates most models. The six main categories are:

1. Models of variables or attributes;
2. Simple models of phenomena;
3. More complex models of phenomena;
4. Models of experiments;
5. Models of interaction among individuals;
6. Models of social institutions and mechanisms [pp. 116-130].

Models of Variables

Most reading models are concerned with identifying and arranging the variables, but we do not understand the structure of most of the attributes that accompany reading behavior. As Luce (1970) pointed out: "Rather than deny our variables, we must learn to isolate and purify them, to measure them, and to relate them one to another in systematic theories [p. 117]."

Furth (1971), in his recent review of 39 studies of the role of language and thinking in deaf subjects, concluded that the "thinking processes of deaf children are similar to those of hearing children and therefore must be explained without recourse to verbal processes [p. 2]." He doubts that early growth in mental ability is due mainly to growth in linguistic skills. This is in harmony with Piaget's position (Inhelder & Piaget, 1964) that "language is not a constituent element of logical thinking [p. 293]."

An effort to increase our understanding of a group of relevant variables in silent reading was made by McGuigan (1970). From data obtained by mechanical sensing devices and electromyography, he drew three major conclusions about covert oral behavior during the silent performance of language tasks:

1. Covert oral behavior increases significantly during the performance of language tasks;

2. The increased covert oral behavior is accompanied by increased respiration rate and increased amplitude of electromyograms in the preferred [writing] arm, but appears to be relatively independent of other oral behavior;
3. Covert oral behavior does not appear typically to increase during the performance of nonlanguage tasks [p. 309].

McGuigan offered five interpretations or explanations of the basic finding of increased covert oral behavior during the performance of language tasks. They range from the extreme centralist position that such covert behavior has no special significance or consequence since information processing, thinking, and other cognitive processes occur exclusively in the brain to the extreme peripheralist position that the oral behavior is both necessary and sufficient for the performance of language tasks.

Simple Models of Phenomena

Most of the reading-related models summarized by Jane Mackworth (1971) and Geyer (1971) fall in this category. Luce (1970) points out that a sizable majority of all psychological models are of this type. Short-term memory is an example. A major difficulty of simple models is isolating the different subprocesses.

Complex Models of Phenomena

Hunt's (1971) distributed-memory model would be classified as complex. Two criteria are given by Luce (1970) for this category: (a) the model is too complex to be stated mathematically and can be formulated only as a computer program; and (b) several intermediate processes are involved and need to be studied in depth.

Models of Experiments

Luce (1970) refers to atheoretical experiments as qualifying for this category. A more appropriate term might be pragmatic studies. A study in reading that compares teaching method "X" with teaching method "Y" (in which properties of the various interactions between methods, pupils, teachers, and milieu are not clearly separated) is typical.

Models of Interaction Among Individuals

Luce (1970) reinforces Entwisle's (1971) conclusion that there is a dearth of models concerned with socially

important contexts that apply to sociolinguistics. Luce is emphatic about our lack of knowledge about how people interact with one another:

> . . . so far, models of small-group [as well as large-group] processes have contributed but little to our understanding of these processes. The fault does not, I think, lie with the model builders, but with the basic intractability of the problem at the present time. On the one hand, there are no remotely adequate models of the individual behaving in a social environment and, on the other hand, there is no real opportunity to aggregate over sufficiently large collections of individuals so that statistical smoothing, as in some economic models, comes to our rescue [p. 129].

Limited examples of individuals interacting do exist, usually in a rational game-theory framework in computer simulation programs.

Models of Social Institutions and Mechanisms

Luce believes that the basic terms in this category are linguistic instead of economic or behavioral. Such models may be important in the development of theories of behavior, and universal aspects of languages undoubtedly reflect deep-seated human constraints. In particular, the study of language learning and concept formation should be affected (Luce, 1970, p. 130). Athey's (1971) presentation of language universals and the biological aspects of language controversy is particularly relevant and may be better understood when models of social institutions and mechanisms are more fully developed.

EDUCATIONAL IMPLICATIONS OF READING MODELS

Singer (1971) specifically considers how reading and learning models relate to pedagogical practices. He points out that Thorndike's stimulus-response model has led to the following practices in teaching reading:

1. Exposure of the stimulus word to the pupil along with the correct oral response;
2. Frequency word counts and basic vocabulary limitation to the most frequently occurring words in most present-day basal readers;
3. Treatment of pupils as passive learners.

On the other hand, instruction stemming from a cognitive learning model emphasizes a purposeful, flexible type of response such as is found in the teaching of reading as one of the language arts with individualized approaches.

Singer (1971) also examines laboratory investigations along with strategies in word recognition, linguistic models, methodological effects, and hierarchical models of acquisition --mainly against the background of a continuum running from stimulus-response to cognitive or field-theory psychology. A comprehensive theory of teaching reading would have to incorporate not only all these aspects but also "cognitive or perceptual learning styles and decision-making [and] criteria for determining strategies for achieving various subgoals . . . such as a rapid rate of initial success with little transfer versus a slow rate of initial success with maximum degree of transfer [p. 7-132]."

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Reading is crossing the divide from a pragmatically oriented Method X-versus-Method Y paradigm to multidisciplinary modeling approaches central to cognitive functioning.

2. Not only is the cognitive emphasis occurring at the language-development, learning-to-read, and reading-process levels but converging evidence is coming from psychology, psycholinguistics, information processing, sociolinguistics, and the biobehavioral sciences--disciplines that view reading macro- and microscopically.

3. Reading modeling is primarily at the identification-of-variable stage, whereas reading-related models are essentially at the simple-and-complex-phenomena stage of development.

4. Variables, or constructs, such as attention, distictive features, pictorial and verbal processing, and short- and long-term memories have been identified from neurophysiology, psychology, and language-development areas.

Recommendations

1. The very early and rapid development of the language (perceptual and cognitive) aspects of reading calls for a longitudinal study encompassing models from at least the five disciplines mentioned above from birth through maturity.

2. All models should compete in an open system. Models that have not met problems posed by other models will either cease to exist or accommodate to data derived from competing models. Further, if pragmatic studies are undertaken, they should exploit existing models and theoretical positions. Most of the existing 100 reading and reading-related models are presented in this report.

3. Strong-inference approaches, such as those outlined by Platt (1964), should be systematically applied in future research.

4. Finally, an information network consisting of an invisible college of scholars representing various points of view should continuously assess models and related research.

REFERENCES

Athey, I. J. Language models and reading. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 6-3 to 6-99.

Bagshaw, M. H., & Benzies, S. Multiple measures of the orienting reaction to a simple non-reinforced stimulus after amygdalectomy. Experimental Neurology, 1968, 20, 175-187.

Bartlett, F. C. Remembering. London: Cambridge University Press, 1932.

Bellugi, U., & Brown, R. (Eds.) The acquisition of language. Monographs of the Society for Research in Child Development, 1964, 29.

Bloom, R. D. Learning to read: An operant perspective. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 7-3 to 7-20.

Brown, R., & Hildum, D. C. Expectancy and the perception of symbols. Language, 1956, 32, 411-419.

Bruner, J. S., Goodnow, J. J., & Austin, M. Studies in cognitive growth. New York: Wiley, 1966.

Chapanis, A. Men, machines, and models. In M. H. Marx (Ed.), Theories in contemporary psychology. New York: Macmillan, 1963. Pp. 104-129.

Chomsky, N. Aspects of the theory of syntax. Cambridge, Mass.: M.I.T. Press, 1965.

Chomsky, N., & Halle, M. The sound pattern of English. New York: Harper & Row, 1968.

Creelman, M. B. The experimental investigation of meaning. New York: Springer, 1966.

Davis, F. B. Psychometric research on comprehension in reading. In F. B. Davis (Ed.), The literature of research in

reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 8-3 to 8-60.

Deese, J. Conceptual categories in the study of content. In G. Gerbner (Ed.), Analysis of communication content. New York: Wiley, 1969. Pp. 39-56.

Elkind, D. Piaget's theory of perceptual development: Its application to reading and special education. Journal of Special Education, 1967, 1, 357-361.

Elkind, D. Reading, logic, and perception: An approach to reading instruction. In D. Elkind, Children and adolescents: Interpretative essays on Jean Piaget. New York: Oxford University Press, 1970. Pp. 136-150.

Entwisle, D. R. Implications of language socialization for reading models and for learning to read. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 6-101 to 6-158.

Fantz, R. L. Visual perception and experience in infancy: Issues and approaches. In F. A. Young & D. B. Lindsley (Eds.), Early experience in visual information processing in perceptual and reading disorders. Washington, D.C.: National Academy of Sciences, 1970. Pp. 351-381.

Furth, H. G. Linguistic deficiency and thinking: Research with deaf subjects, 1964-1969. Psychological Bulletin, 1971, 75, 58-72.

Gagné, R. M. The conditions of learning. (2nd ed.) New York: Holt, Rinehart, & Winston, 1966.

Gephart, W. J. Application of the convergence technique to basic studies of the reading process. Bloomington, Ind.: Phi Delta Kappa, 1970.

Geyer, J. J. Comprehensive and partial models related to the reading process. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 5-1 to 5-51.

Gibson, E. J. Principles of perceptual learning and development. New York: Meredith Corporation, 1969.

Gibson, E. J. The ontogeny of reading. The American Psychologist, 1970, 25, 136-143.

Gibson, E. J., Osser, H., Schiff, W., & Smith, J. An analysis of critical features of letters, tested by a confusion

matrix. In H. Levin et al., A basic research program in reading. Ithaca, N. Y.: Cornell University, 1963.

Gillooly, W. B. The influence of writing-system characteristics on learning to read. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 7-21 to 7-43.

Goodman, K. S. Analysis of oral reading miscues: Applied psycholinguistics. Reading Research Quarterly, 1969, 5, 9-30.

Goodman, K. S. Reading: A psycholinguistic guessing game. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 259-271.

Hansen, D. N. Information-processing models for reading-skill acquisition. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 7-45 to 7-71.

Hochberg, J., & Brooks, V. Reading as an intentional behavior. In H. Singer & R. B. Ruddell. Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 304-314.

Holmes, J. A. The substrata-factor theory of reading: Some experimental evidence. In J. A. Figurel (Ed.), New frontiers in reading. New York: Scholastic Magazines, 1960. Pp. 115-121.

Hubel, D. H., & Wiesel, T. N. Receptive fields of single neurons in the cat's visual cortex. Journal of Physiology, 1959, 148, 574-591.

Hubel, D. H., & Wiesel, T. N. Receptive and functional architecture of monkey striate cortex. Journal of Physiology, 1968, 195, 215-243.

Hunt, E. What kind of computer is man? Cognitive Psychology, 1971, 2, 57-98.

Hydén, H. Biochemical aspects of learning and memory. In K. Pribram (Ed.), On the biology of learning. New York: Harcourt, Brace & World, 1969. Pp. 95-125.

Inhelder, B., & Piaget, J. The early growth of logic in the child. New York: Harper & Row, 1964.

Jakobson, R., & Halle, M. Fundamentals of language. The Hagne: Mouton, 1956.

Katz, J. J., & Postal, P. M. An integrated theory of linguistic descriptions. Cambridge, Mass.: M.I.T. Press, 1964.

Kingston, A. J. Disjunctive categories in ephemeral models. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 8-61 to 8-65.

Kuhn, T. S. The structure of scientific revolutions. Vol. 2. (2nd ed.) Chicago: University of Chicago Press, 1970.

Laffal, J. Pathological and normal language. New York: Atherton, 1965.

Lenneberg, E. H. Biological foundations of language. New York: Wiley, 1967.

Lettvin, J., Maturana, H., McCulloch, W., & Pitts, W. What the frog's eye tells the frog's brain. Proceedings of the Institute of Radio Engineers, 1959, 40, 1940-1951.

Levin, H., & Kaplan, E. L. Grammatical structure and reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. Pp. 119-133.

Liberman, A. M., Cooper, F. S., Shankweiler, D. P., & Studdert-Kennedy, M. Perception of the speech code. Psychological Review, 1967, 74, 431-461.

Lionnais, F. L. Cybernetics. In R. Taton (Ed.), Trans. by A. J. Pomerans, History of science, science in the twentieth century. Vol. 4. New York: Basic Books, 1966. Pp. 60-73.

Lorenz, K. Innate bases of learning. In K. H. Pribram (Ed.), On the biology of learning. New York: Harcourt, Brace & World, 1969. Pp. 13-93.

Luce, R. D. What are mathematical models of behavior models of? In R. M. Stogdill (Ed.), The process of model-building in the behavioral sciences. Columbus: Ohio State University Press, 1970. Pp. 115-132.

Mackworth, J. F. Some models of the reading process: Learners and skilled readers. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 8-67 to 8-100.

Mackworth, N. H. Seven cognitive skills in reading. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 8-101 to 8-127.

McGuigan, F. J. Covert oral behavior during the silent performance of language tasks. Psychological Bulletin, 1970, 74, 309-326.

McNeill, D. The development of language. In P. H. Mussen (Ed.), Carmichael's manual of child psychology. Vol. 1 (3rd ed.) New York: Wiley, 1970. Pp. 1061-1161.

Menyuk, P. Language theories and educational practices. In F. Williams (Ed.), Language and poverty. Chicago: Markham Publishing, 1970. Pp. 190-211.

Miller, G. A., Galanter, E. H., & Pribram, K. H. Plans and the structure of behavior. New York: Holt, 1960.

Neisser, U. Cognitive psychology. New York: Appleton-Century-Crofts, 1967.

Osgood, C. E. Interpersonal verbs and interpersonal behavior. Technical Report No. 64. Urbana: University of Illinois, Group Effectiveness Research Laboratory, 1968.

Piaget, J. Piaget's theory. In P. H. Mussen (Ed.), Carmichael's manual of child psychology. Vol. 1. (3rd ed.) New York: Wiley, 1970. Pp. 703-732.

Platt, J. R. Strong inference. Science, 1964, 134, 347-352.

Pribram, K. H. Toward a science of neuropsychology: Method and data. In R. H. Patton (Ed.), Current trends in psychology and the behavioral sciences. Pittsburgh: University of Pittsburgh Press, 1954. Pp. 115-142.

Pribram, K. H. Reinforcement revisited: A structural view. In M. Jones (Ed.), Nebraska symposium on motivation. Lincoln: University of Nebraska Press, 1963. Pp. 113-159.

Pribram, K. H. Some dimensions in remembering: Steps toward a neuropsychological model of memory. In J. Gaito (Ed.), Macromolecules and behavior. New York: Academic Press, 1966. Pp. 165-187.

Pribram, K. H. (Ed.) On the biology of learning. New York: Harcourt, Brace & World, 1969.

Roberts, G. R., & Lunzer, E. A. Reading and learning to read. In E. A. Lunzer & J. F. Morris (Eds.), Development in human learning behavior. Learning: Education. Vol. 2. New York: American Elsevier Publishing, 1968. Pp. 192-224.

Ruddell, R. B. Psycholinguistic implications for a systems-of-communication model. In H. Singer & R. B. Ruddell (Eds.),

Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 239-258.

Samuels, S. J. Success and failure in learning to read: A critique of the research. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 7-73 to 7-114.

Schiffman, H. R. Sensory and perceptual aspects of the reading process. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 8-129 to 8-153.

Singer, H. Theories, models, and strategies for learning to read. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 7-115 to 7-139.

Smith, F. Understanding reading: A psycholinguistic analysis of reading and learning to read. New York: Holt, Rinehart, & Winston, 1970.

Sokolov, E. N. The modeling properties of the nervous system. In M. Cole & I. Maltzman (Eds.), A handbook of contemporary Soviet psychology. New York: Basic Books, 1969. Pp. 671-704.

Staats, A. W. Learning, language, and cognition. New York: Holt, Rinehart, & Winston, 1968.

Staats, A. W., Brewer, B. A., & Gross, M. C. Learning and cognitive development: Representative samples, cumulative-hierarchical learning, and experimental-longitudinal models. Monographs of the Society for Research in Child Development, 1970, 35, 1-85.

Staats, A. W., & Staats, C. K. A comparison of the development of speech and reading behavior with implications for research. Child Development, 1962, 33, 831-846.

Stogdill, R. M. Introduction: The student and model-building. In R. M. Stogdill (Ed.), The process of model-building in the behavioral sciences. Columbus: Ohio State University Press, 1970. Pp. 3-13.

Tikofsky, R. S., & McInish, J. R. Consonant discrimination by seven-year-olds: A pilot study. Psychonomic Science, 1968, 10, 61-62.

Wanat, S. F. Linguistic structure in reading: Models from the research of Project Literacy. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 8-155 to 8-177.

Wardhaugh, R. Theories of language acquisition in relation to beginning reading instruction. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 6-159 to 6-185.

Weaver, W. W., & Kingston, A. J. Modeling the effects of oral language upon reading language. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 8-179 to 8-192.

Wiesel, T. N., & Hubel, D. H. Spatial and chromatic interactions in the lateral geniculate body of the rhesus monkey. Journal of Neurophysiology, 1966, 29, 1115-1156.

Weisstein, H. What the frog's eye tells the human brain: Single cell analysis in the human visual system. Psychological Bulletin, 1969, 72, 157-176.

Williams, J. P. Learning to read: A review of theories and models. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 7-141 to 7-165.

SECTION 3

SYNTHESIS OF PAPERS ON LANGUAGE DEVELOPMENT AND READING

Irene J. Athey

University of Rochester

The three papers represent a diversity of orientation. Each writer, while fully cognizant of the efforts of the other two, has pursued his or her own bent regarding interpretation of the task, the route by which the goal should be attained, and the final product. This diversity permitted each contributor to bring the strengths of his discipline, its mode of inquiry, and its research literature to bear on the topic even if this made the final task of integration of the three viewpoints more difficult. However, the three papers provide an unexpected but fortunate unanimity of perspective which suggests that benefits may accrue from interdisciplinary efforts of this kind other than those associated with convergence on a common problem.

Before elaborating on the general points of agreement expressed in the three papers, it might be well to discuss briefly the differences which characterize them. The primary objective, it may be remembered, was to identify major models of language, to disclose their inherent assumptions, explicit or implicit, and to review the pertinent literature to determine the extent to which hypotheses derived from the models had been tested. The selection of models posed a number of questions. The obvious choice would have been to select models of language as it functions in reading. However, a quick survey showed that no models exist which address themselves specifically to language in this context. Language, or a component of language (such as vocabulary), may feature as one or a few elements among many in a systems-type model, but in this project such models were to be considered by two other teams working in the areas of reading and learning to read. It was also apparent that the task of the language group was of a different order from that of the other two groups, whose activities were focused directly on the reading or learning-to-read process. The group's approach had to be indirect. It would examine the existing models in its domain first in their own right, and then seek to determine their implications for

reading. A decision was made to exclude models of adult language and to concentrate on models of language development in children, since it seemed likely that the latter would have more relevance for reading and especially for learning to read.

We were aware, of course, of the rapidly growing body of new literature in the area of sociolinguistics which could not be ignored, even though there were no well-known models representing the area. One member of the team, Doris Entwisle of Johns Hopkins University, was assigned specifically to review the current status of the field of sociolinguistics.

Entwisle has completed a thorough review of the major issues and research literature in sociolinguistics. As expected, her paper differs from the other two in that it does not identify a single model of language acquisition or language functioning.* This absence of models in sociolinguistic theory may be a function of the relative newness of the field. On the other hand, it is possible that most sociolinguists agree with Entwisle in viewing existing models as inadequate to deal with those group differences which constitute the subject matter of their inquiry.

The other two papers by Athey and Wardhaugh deal exclusively with models of language acquisition. Models of adult language were excluded deliberately by both authors as being minimally pertinent to reading. While there is some overlap in the models discussed in the two papers, the orientation and coverage are different, and the implications appear, at least on the surface, to be quite different, in places even contradictory. For example, Wardhaugh enumerates several crucial differences between the process of acquiring language and that of learning to read. He concludes that, since there is no parallel between the two processes, language-acquisition models can have few or no implications for reading. Athey, on the other hand, views at least some of these differences as imposed by the educational system, and suggests that if some of these impositions were removed, the differences would tend to disappear. The discrepancy may also be a function of the models reviewed since, as might be expected, Wardhaugh has concentrated on linguistic models which portray the language-acquisition process as virtually completed by the time the child is four or five years old, and certainly before he is called upon to begin the task of reading, while Athey is more

---

*Entwisle does attempt in one section of her paper to relate some of the major variables of sociolinguistic theory to existing models, but it is noteworthy that she chooses models of reading rather than models of language for this purpose. This choice suggests that the issues currently engaging the interest of sociolinguists may be closer to those of the reading specialist than of the traditional linguist.

concerned with certain psychological models, especially those relating language growth to the emergence of cognitive maturation.

As previously noted, these differences are more apparent than real. On the underlying philosophy of language, or perhaps more broadly of education, there was substantial agreement. The overriding principle of agreement may be summarized in the statement that reading is not a "skill" or even a bundle of skills, but a system of social communication. This somewhat trite statement, if taken seriously, has far-reaching implications for education, because it means that reading is not viewed as a "subject" in the curriculum, not even the subject which receives most emphasis in terms of time and resources. It is viewed rather as one part of the fabric of living and problem solving which <u>ought</u> to be the focus of the school's efforts in organization, planning, and curriculum. In this view, the task of learning to read is not a matter of breaking down the reading task into a number of component skills and determining the order in which these skills should be taught. Instead, it involves above all the realization that the printed word is another system of communication analogous to speech. Hence, as in spoken language where the child learns to behave according to a set of induced rules, learning to read means learning strategies for attacking and solving problems of recognition and meaning.

It follows that the experience which a child has had with problem solving in general will have a pronounced effect on the attitudes and approach he brings to solving this particular problem. Wardhaugh makes the point with respect to language when he says, "Language is only one part of the six-year-old's life. He takes it for granted, much as he takes breathing for granted [personal communication]." In a highly technologized, literate society, where a vast amount of information is conveyed through the printed medium, reading should be equally a part of the child's life, not one which looms as a difficult and irrelevant task, but as an integral part of his daily activity.

A related point, which also evoked considerable agreement, was that the social context in which reading occurs is of paramount importance. Entwisle's major interest is in the correlates of reading and socioeconomic status, where socioeconomic status is used as a blanket term for a loosely related set of economic, social, and psychological factors ranging from educational level to deep-seated attitudes. The task is to determine which of these many variables are the ones most critical to learning to read. Entwisle points to Bernstein's work, which attempts to disentangle the threads of the many social variables that affect language, and suggests that parallel work is needed on the relationship of these and other social variables to reading. In particular, she emphasizes

the cognitive strategies and affective attitudes which have their origin in the home and are already well entrenched by the time the child goes to school. It becomes apparent that the child-rearing practices in the home, which will determine the young child's orientation toward codes, his perception of familial and social roles, his willingness to take risks, his control beliefs, and other cognitive-affective characteristics, are probably among the most crucial in determining beginning reading ability.

As indicated, Entwisle documents each of these variables with research findings, but does not relate them to the language models. Before we discuss the ways in which sociolinguistic research may be integrated with the basic models, a slight digression is necessary to consider further points of agreement in the discussion of linguistic models.

Wardhaugh considers the opposition between linguistic and learning-theory descriptions of language acquisition and concludes that the latter are totally inadequate to account theoretically for the known facts. However, he views Slobin's account of language acquisition as the most promising. Slobin sees a need to postulate linguistic concepts, such as Chomsky's Language Acquisition Drive (LAD), and other innate features of language, but he also sees a role for learning principles, without specifying what these principles are. It is clear that learning-theory concepts (such as reinforcement, imitation, generalization, and the like) cannot provide a totally satisfactory explanation of the development of language. On the other hand, it is also apparent that these concepts have proved to be valid and useful in accounting for learning in both theoretical and practical contexts. If some aspects of language are attributable to learning, it seems reasonable to suppose that principles that have been shown to be valid in other areas of learning should be applicable to the learning of language. The immediate task seems to be to determine which aspects of language are learned and which concepts of learning theory are most appropriate to the task of explaining those aspects. Linguists have tended to ignore these concepts for two reasons: first, because having shown that behaviorist theories cannot now explain <u>all</u> the phenomena of language, especially the important feature of abstraction, they have tended to assume that behaviorist principles cannot explain <u>any</u>, except perhaps trivial aspects; second, because in awe of the "astonishing rapidity" with which the child grasps the basic elements of the language system, they have tended to ignore the continuous growth of certain aspects of language through the school years. It is possible that learning principles may have more application to language learning during this period than in the primary language period of infancy.

The foregoing discussion might seem to suggest that what is called for is some modification or loosening of

linguistic theory to accommodate principles or constructs taken from learning theory. However, at least one of the authors takes the position that a more fruitful approach would be to incorporate the known facts of language acquisition into a broader theory of cognitive development. The behaviorist principles enumerated above should also be considered within this theoretical framework, because the appropriateness of these principles is a function of the cognitive maturity of the individual. Piaget has pointed out that the efficacy of a stimulus both as a cue to action and as a reinforcer is dependent on the particular structures possessed by the child. Similarly, imitation and mediation are not equally valid at all age levels.

Cognitive theories, such as those of Piaget and Bruner, while acknowledging the importance of language, do not explain specifically how language affects and is affected by the child's developing cognitive powers. Piaget states that there is nothing in the work of Chomsky and others which contravenes his theory. In that case, it should be possible to integrate some of the concepts of the two theories. On the other hand, linguists differ among themselves, and it is not clear whether Piagetian theory is most hospitable to Chomsky's account or to those of some other linguistic theorist. Since reading is a product of both cognition and language, a clarification of the relationship between these two functions is necessary to understand the mental processes involved in reading.

In essence, if the approach to understanding reading through the medium of theoretical models is a viable one, what seems to be called for is a cognitive theory (e.g., Piaget or Bruner), or a psycholinguistic theory that leaves room for learning (e.g., Slobin), or some composite of the two. Other theories, such as that of Lenneberg or of the advocates of the information-processing approach, provide additional insights from the perspective of other disciplines, but the foundation lies essentially in some form of cognitive theory. This is the conclusion reached in the two papers which address themselves to language models.

We may return now to Entwisle's contribution and to its implications for model building. Two points which emerge rather clearly are: first, no model, however sophisticated, makes provision for group or individual differences, although such differences are crucial factors in learning; and second, given an acceptable model, the tendency has been to view individual or group aberrations from that model in terms of deficit rather than in terms of differences. Such a view is misleading because it encourages teachers to provide programs to repair or compensate for the deficit, instead of urging them to look for ways of teaching which capitalize on the differences and which place learning in the appropriate social context. Language enrichment in a difference, rather than a deficit, model becomes more than a matter of increasing vocabulary or labeling

objects. It means recognizing the existing language potential of the child and using it to develop flexibility between his own language system and that of the dominant culture.

For the time being, it appears that sociolinguistics needs to develop its own working models, for there is a dearth of hypothesis-generating theory in this area. Such models, in addition to representing language development in different groups, may serve to draw attention to anomalies in the basic models. If, as Entwisle suggests, social class membership affects such things as what is attended to and what meanings are assigned to perceptions, perhaps these processes are affected by other variables besides social class. Her analysis proceeds to the consideration of differences in cognitive style processes, control beliefs, willingness to take risks, role relationships, and reliance on nonlinguistic cues for information processing associated with social class, but social class is not the only factor which affects these characteristics. The importance of these variables in determining linguistic and reading behaviors has been demonstrated for urban children. This suggests that insufficient attention has been given to these factors in the general models of either language or reading. Additionally, the models usually fail to specify the interaction among the various components or subprocesses represented descriptively or pictorially. This is a critical omission because it ignores the possibility of compensation for deficiency in one variable by means of superiority in another or by means of their interaction. In other words, models should be concerned not only with the characteristics--skills, processes, etc.--involved but with the kinds and amounts of these characteristics and the interactions among them.

We may conclude from the three papers that we are a long way from achieving a comprehensive model of either reading or language or from an integrated model of the two processes. We have suggested that the ideal model of language is one that will recognize the interdependence of cognitive maturation and language development, will clarify the respective roles of genetic factors and learning, will account for all the variables involved, and will take cognizance of the interaction among them. Until such a model is forthcoming, we need models which may be partial in the sense that they explain only restricted portions of the total process or in the sense that they represent only a subgroup's mode of functioning rather than the basic process _per se_. These partial models will tell us how language functions for children of different ages and backgrounds in different social and educational contexts. Until such time as we have even these partial models, perhaps the best guideline we have is, in Entwisle's words, "those children who learn to read best are those who need to in order to make sense of their lives." As educators, we should begin to affect the environment in such a way that reading begins to make sense in children's lives.

SECTION 4

LEARNING TO READ:

SIX PAPERS IN SEARCH OF A MODEL

Joanna P. Williams

University of Pennsylvania

The papers that represent the Literature Search's work on learning to read reveal, on the one hand, the great diversity of points of view in the area, and, on the other, some important points of consensus. Our objectives were to identify the major models of reading acquisition and to delineate the assumptions inherent in each one. In addition, the literature was reviewed in depth in order to evaluate the models in terms of whatever empirical evidence was available. Each contributor worked independently, interpreting his assignment in the light of his own orientation and focusing on his task in what he considered to be the most meaningful manner. As was true in the other two areas, Language Development and Reading Processes, these papers, taken together, demonstrate the fruitfulness of this approach.

As expected, the papers differ in character. Each of them focuses on a specific theoretical orientation. Richard Bloom discusses the operant model; S. Jay Samuels, the associative-learning model; and Duncan Hansen, the information-processing model. William Gillooly's paper deals with writing systems; he searches for models of language and learning that relate to characteristics of and variations in orthography. Joanna Williams reviews a variety of models that are cognitively and psycholinguistically based, and Harry Singer discusses several types of models, with emphasis on how to get from models of learning to read to models of instruction. These papers demonstrate clearly the value of the model approach and also the viability of a variety of extant models.

A brief overview of each paper will be presented here, followed by some general conclusions about the area as a whole.

Bloom, in his study of the ways in which operant-learning concepts can aid our understanding of reading behavior, describes and evaluates both the process of learning to

read and the design of instructional paradigms. He points out (a) the value of the operant framework in terms of an analysis of typical instructional situations, and (b) how to modify the situation according to what the theoretical analysis prescribes. Bloom outlines some of the difficulties of this approach, including the problem of defining the response units to be strengthened (because reading does not possess easily identifiable and meaningful characteristics). Yet it is obvious that the operant approach has, indeed, been fruitful--witness the work of Staats and others, indicating that rudimentary reading skills, at least, can indeed be acquired under systematized operant procedures. Indeed, the Skinnerian approach has shown itself to be of enormous practical value in terms of providing the bases for developing effective and efficient training procedures for simple tasks.

A considerable portion of Samuels' paper consists of a review of associative learning, which culminates in the author's proposal of a model of associative learning specifically designed to relate to reading. As Samuels indicates, the associative-learning paradigm has a long history, and it has been used extensively both in reading research and as a basis for instructional paradigms. Samuels' work points up, however, the enormous changes in what we now consider to be "associative learning." Having been introduced as a simple model, it is now quite complex. Samuels reviews the fundamental components of associative learning, which include attention, visual and auditory discrimination, short-term and long-term memory, and mediation. In its present state of development, the model can reclaim its usefulness as a paradigm for reading, for it acknowledges the great complexities inherent in the reading process. In fact, recent developments in the associative model may mean a fresh start for this approach in terms of research potential.

Information-processing models, on the other hand, have very little history as far as utility for reading research is concerned. But, Hansen suggests, they have a very promising future. Hansen emphasizes the value of this approach for representing complex, hierarchically-structured processes. Moreover, such a model can be represented via a computer program, which makes for ease of explicit alteration and development. Chosen because of their potential usefulness for dealing with the reading process, three types of information-processing models are reviewed in this paper: Simon's General Problem Solver, interactive natural language models, and Atkinson's instructional models. There is at present enough research on human cognitive processes to indicate the value of this approach to the study of reading. Hansen predicts that within a few years the information-processing approach will be widely used by research workers in reading.

Gillooly's report indicates the great complexity of the orthographic system. "One-sound, one-symbol" does not

apply. Rather, complex rules govern the correspondences between sound and symbol, and these rules are at several levels of generality. Gillooly reviews, for example, Chomsky's assertion that there is an underlying abstract system (the level of lexical representation) which maps to both the orthographic and the spoken language. Such analyses indicate far more regularity in our writing system than has been commonly acknowledged. Our writing represents elements of meaning as well as elements of sound. In addition, Gillooly examines relevant data on the use of transitional writing systems, such as i.t.a. and cross-national data.

Williams' paper studies models that have a cognitive framework, including those of the Cornell group, Elkind, Venezky, and Calfee; and those that have a strong linguistic orientation, such as Goodman's and Ruddell's. This general approach is characterized by an emphasis on the active nature of the learner, on the complex perceptual and cognitive strategies involved in sampling the cues on the printed page and developing and testing hypotheses, and on the complexity and importance of the language system. While most theoretical interest has lately been focused on the proficient reader, there is also interest in the process of acquisition. Much of the work on learning to read has emphasized decoding, although it is almost universally acknowledged that, however defined, decoding remains only a small part of "reading."

Singer discusses the value of the model-building approach not only for understanding the processes involved but also in terms of implications for educational strategies. He considers learning theory, cognitive theory, and linguistic theory. So far, cognitive theory has not been employed extensively in this regard. Singer discusses the hypothesis that different instructional strategies may lead to different outcomes, not necessarily in terms of overall reading ability but perhaps in terms of components. For example, one type of instruction might promote word-recognition skills but at the expense (relatively speaking) of comprehension. Moreover, the effectiveness of a given strategy might depend on ability level, cognitive style, and other such factors. Singer outlines what is needed in order to develop a viable theory of instruction.

This short summary should suffice to demonstrate the breadth of the field and the diversity of approaches represented in these papers. One fundamental distinction has been pointed out by Bloom: the difference between (a) the behaviorist perspective, with its emphasis on the objective description of environmental events that might influence reading behavior, and (b) the cognitivist position, which stresses the internal processing of information. This question of scientific strategy is, of course, a much larger issue, and it seems to the present writer that choice of strategy may have important

implications not only for model-building per se but also for the application of theory to questions of instruction.

The basis on which the models have been developed differ greatly. In some cases (e.g., Gibson, Samuels), experimental data provide an empirical base. Goodman analyzes errors (miscues) made during oral reading. Ruddell looks at data from classroom comparisons; others emphasize data collected in small-group (e.g., Elkind) or tutorial situations (e.g., Staats). Singer's approach is psychometric. Other models are constructed logically, not empirically--inspired, perhaps, by models developed in other areas. And, of course, no theorist has necessarily been tied to any single base.

But a summary statement should concentrate on the rapprochements among the several approaches, for the similarities among the models are much more meaningful than the differences. I shall list some of the general points of coggruence as I see them. All of these issues have not been raised in every one of the six papers but, overall, there is consensus.

1. The most promising type of model seems to be one with a cognitive framework; most recent models are of this nature. I am including in this group the information-processing models discussed by Hansen. Moreover, two more traditional approaches--operant learning and associative learning--are currently undergoing modification in directions that are definitely in line with the cognitive approach.

2. The notion of reading as a complex skill or set of skills often goes hand in hand with a cognitive point of view. Exactly what the component skills are and how they relate to each other is as yet undetermined. While some theorists claim that the process of reading cannot be broken down for study (e.g., Goodman), others feel that this is the only viable approach.

3. Reading is a communication (i.e., language) process, and comprehensive models will have to take into account the complexity of the language system. A start has been made; transformational-generative grammar has been most influential to date.

4. The beginning reader is usually a child. Thus, a theory of reading acquisition must acknowledge developmental status. Of course, what this means--that is, what abilities and processes differ in the immature vs. the mature individual and how they differ--depends on one's theoretical posture. Singer's model, for one, deals with this question explicitly.

5. Little has been done to incorporate affective factors into models of reading acquisition. Obviously, reading

is seen as a purposive activity, the goal of which is often described in terms of getting information. A typical way of handling topics such as motivation and values, when they are considered at all, is to consider them as "mobilizers" (e.g., Ruddell) which become operationalized as objectives. Work within the Holmes and Singer system has for the most part indicated that affective factors are relatively unimportant variables.

It seems to me that one reason for the neglect of affective factors is, in fact, that much of what used to be considered "affective" is becoming integrated into general concepts of cognition. The literature on cognitive style is an example. Attention, too, has become an important element of cognition, as Samuels' paper indicates. Entwisle's paper (in Section 6, Language Development) explores this area in depth.

6. Little emphasis has been given to individual and group differences. This seems reasonable in view of the fact that models of reading and of learning to read are still in a very early state of development. It is obvious, however, that to be complete, models will have to take such differences into account.

7. The manner in which a model of reading acquisition may be used for developing effective instruction has not been fully worked out. Singer's paper indicates that theories have indeed been influential in general ways. However, we do not yet have many specific, theoretically based procedures for devising instructional paradigms. Coleman's proposal for the use of educational engineering in the translation of theory to practice (cited by Singer) is promising.

8. We do not have a comprehensive model of learning to read. We do not even have a comprehensive model of mature reading on which we might base an acquisition model. Perhaps it will be more profitable for a while to concentrate on partial models; that is, formulations that deal with limited aspects of what we generally call reading.

SECTION 5

COMPREHENSIVE AND PARTIAL MODELS RELATED TO THE READING PROCESS

John J. Geyer*

Rutgers University

INTRODUCTION

For the past year, six reviewers† working in collaboration with each other and with other consortium members have reviewed the literature relating to the reading process within specific areas of expertise. The strategy employed in this review was to identify and evaluate (a) that literature which presented models or partial models of, or related to, the reading process; (b) research studies judged to support or disconfirm existing models or which identified elements that could extend or relate existing models; and (c) pertinent non-research materials. Each study selected was categorized on several dimensions and evaluated according to a standard format designed to facilitate integration.

In the following section of this report are papers from each reviewer and from several advisory-panel members that summarize their individual efforts in evaluating the contributions of their respective areas to an understanding of the reading process. Major attention in these papers is directed to the theoretical issues and related research that constitute the leading edges of current knowledge in each area in relation to the reading process. Thus, the primary responsibility for interpretation and critical judgment remained with the scholars who are expert in the fields surveyed and who were personally involved in the review of the literature.

This section systematically reviews those articles and books selected and evaluated by the reviewers as having presented comprehensive or partial models of the reading process

---

*The writer was coordinator of the reading-process area and Associate Director of the project.

†Reviewers in the reading-process area were F. B. Davis, J. Mackworth, N. Mackworth, R. Schiffman, S. Wanat, and W. W. Weaver. Advisory Panel members providing support to these reviewers were R. Efron, A. Kingston, P. Kolers, and K. Pribram.

and of processes related to reading. It is based on the formal evaluations of the reviewers, supplemented by a reading of the original work reviewed. Categorizations of the models are those of the reviewers; this section makes full use of the information presented by them. Since the material in this section is often twice removed from the original thinking of the authors reviewed, the emphasis is on a comprehensive coverage of models concisely described rather than upon integration of elements, criticism, or relationships to research findings. A reading of this section, therefore, will in no way substitute for a reading of the contributions of the individual reviewers--indeed, the section is intended to provide a broad overview helpful in placing the reviewers' papers in a meaningful context.

Definitions of Models

The basic planning document underlying the Literature Search (Gephart, 1970) defines a model as ". . . a representation of a phenomenon which displays the identifiable structural elements of that phenomenon, the relationships among those elements, and the processes involved in the natural phenomenon [p. 38]." Such models should be capable of serving three general purposes: ". . . to explain what a complex phenomenon consists of; to describe how such a phenomenon works; and to provide the basis for predictions about changes which will occur in one element of the phenomenon when changes are made in another element [p. 40]." As clear as that definition is, it proved difficult to apply operationally across different disciplines. Extended discussions at the several consortium conferences revealed wide ranges of opinion concerning exact criteria for the identification of models. Consequently, each reviewer applied his own criteria within his own area of concern.

Definitions of the Reading Process

Scholars familiar with the professional literature in reading are aware of the acute difficulties involved in developing an adequate definition of reading. Many of the theoretical disputes in the field are essentially questions of definition. Any predetermined definition, therefore, inevitably has the effect of eliminating potentially germane studies that some authorities would consider related to reading. Consequently, reviewers were asked to use their own definitional structures while erring on the side of inclusiveness. The definitions employed are discussed in the papers by the individual reviewers. This policy resulted in the inclusion of models that intuitively seemed related to the reading process, but for which the exact relationships remain obscure. Such models, of course, broaden a research base and should be particularly fruitful in research generation.

Selection of Models

Ninety-seven references were evaluated by the reviewers that were categorized as presenting comprehensive or partial models of the reading process or of processes related to reading. Consolidation of multiple references to single models and evaluations of the same models by more than one reviewer produced 77 distinct works classified within the model category. Inevitably, much disagreement could be generated over the inclusion or exclusion of particular models. This writer, employing a generously vague interpretation of Gephart's definition, has selected 45 of the reviewed models for inclusion in this section. Several of the models not included are primarily concerned with language or with learning to read and will be treated in other sections of the report. The references not included are listed in the bibliography. To the included models will be added three models for which formal reviews were not received; viz., the comprehensive model of reading developed by J. Mackworth as part of the Literature Search (Mackworth, 1971), the reading-process aspects of the Reading Competency Model of Venezky and Calfee (Venezky & Calfee, 1970), and Sperling's most recent model of visual information processing (Sperling, 1970). All models reviewed except two were classified as having been developed from a research base and all were classified as having research generation as a primary function. The 48 models will be grouped in the following categories as assigned by the reviewers: (a) comprehensive models specifically of the reading process, (b) comprehensive models of processes related to reading, and (c) partial models of processes involved in or related to reading.

COMPREHENSIVE MODELS OF THE READING PROCESS

The eight models of the reading process classified as comprehensive comprise a representative sample of the disciplines and approaches to model building found within the total body of models. The models differ from one another not only in their approach to model building but to some degree in what they seek to explain. The earliest of the models included is Holmes's Substrata-Factor Theory, first published over twenty years ago (Holmes, 1948). The remainder range in dates from the writer's model of perception in reading (Geyer, 1966) to J. Mackworth's comprehensive model published for the first time in this report (J. Mackworth, 1971). In these dates can be seen both the recency of the modern effort to develop a sound theoretical understanding of the reading process and the pioneering contribution of Holmes to this effort.

The Substrata-Factor Theory of Reading

The Substrata-Factor Theory of Reading (Holmes, 1948, 1965, 1970), the most ambitious attempt at theory building in reading over a twenty-year period, is well known to scholars of the reading process. Holmes presented his theory as three related models: neurological, psychological, and statistical. Primary emphasis, however, was given by him and the field to the latter two. At the base of the psycholcgical model lay the substrata factors, thought of as

> . . . neurological subsystems of brain cell-assemblies, containing various levels of information; such as, memories for shapes, sounds, and meanings of words and word parts, as well as memories for vicarious and experiential material, conceptualizations, and meaningful relationships stored as substantive verbal units in phrases, idioms, sentences, etc. [Holmes, 1970, p. 188].

Such substrata factors can be flexibly combined into working systems, thereby bringing together diverse information learned at various times and under different circumstances to the immediate task of the reader. Working systems of diverse substrata factors are initially organized by the "psychocatalytic" action of mobilizers, electrochemical biases in the brain's scanning-search mechanisms closely related to deep-seated value systems at a psychological level. Once organized, a working system can be triggered by appropriate printed symbols. Improvement in reading ability involves the development and enrichment of working systems and the increasing interfacilitation of substrata factors within and between working systems. Developmentally, the theory postulates that as a child matures in his reading skills, the hierarchically organized working systems will undergo gradient shifts, that is, initially complex working systems will be subsumed within higher-order working systems. To test the theory, Holmes employed as the statistical model an extension of the Wherry-Doolittle test-selection procedure which has generated considerable controversy. The use of this statistical model has been criticized extensively by Davis (1971) in this report.

The Roberts and Lunzer Model

Roberts and Lunzer (1968) view reading as a type of listening with visual input. As such, it is a skilled behavior requiring a high degree of automatization of the subskills and their sequencing. At every stage of the process, there is uncertainty which is reduced by the ongoing process of obtaining information. This general principle holds not only for those "molar" categories of behavior which are conscious but also extends to those behaviors that have been so fully automatized that they are performed without awareness. As a

linguistic process, reading reflects the constraints of language as a whole, and in particular of spoken language. It is through these constraints that reading is possible, as they ". . . mediate the transition from those non-linguistic states of uncertainty to the skill itself and the relevance of the skill behaviour to the reduction of such uncertainty [p. 204]."

Figure 1 presents the schematic representation of the hierarchical and sequential organization of reading behavior as modeled by Roberts and Lunzer (1968, p. 203). Represented are the decision processes or strategies, perceptuo-motor mechanisms, and active memory states of processes of skilled reading. At the two lower levels of regulation are the control of strategic effector coordination through systems of neuromuscular regulation of head and eye movements, focusing, etc. On the receptor side is the comparator system which provides a heightened sensitivity to a specific range of patterned input through the peripheral mechanisms involved in perception. Five additional levels are shown, which regulate perceptuo-motor behavior in progressive stages of effector coordination and perceptual sensitivity. Lower-level strategies are subordinated to higher-level strategies that operate over longer time intervals. Therefore, each lower-level strategy must be stored in immediate memory until the whole process is complete; that is, when uncertainty reduction has occurred at the level of the passage.

The Venezky and Calfee Model

Figure 2 presents a schematic diagram of the model of the reading process developed by Venezky and Calfee (1970). Essential processes in this model are high-speed visual scanning, dual processing, and a search for the largest manageable unit (LMU). The two forms of processing, which generally take place simultaneously, are (a) syntactic-semantic integration of what has just been scanned, and (b) forward scanning to locate the next LMU. The LMU's are the largest units that can be chunked rapidly and may be single letters, strings of letters, words, or phrases. Word identifications are first sought through a search of the associative word store (AWS) where the most frequently encountered words are organized for retrieval on the basis of initial letters, final letters, and word length. An item not matched in the AWS will be compared to items in the Low-Frequency Store (LFS). Other stores involved in the process are the Integrated-Knowledge Store (IKS), which contains the reader's stable knowledge concerning how reading works, sentence types, etc.; the Integrated Letter Store (ILS), which contains information on letters and letter expectancies; and the Temporary Knowledge Store (TKS), where the integrated information about what is being read is processed from the shorter-term store called the Scratch-Pad Store (SPS).

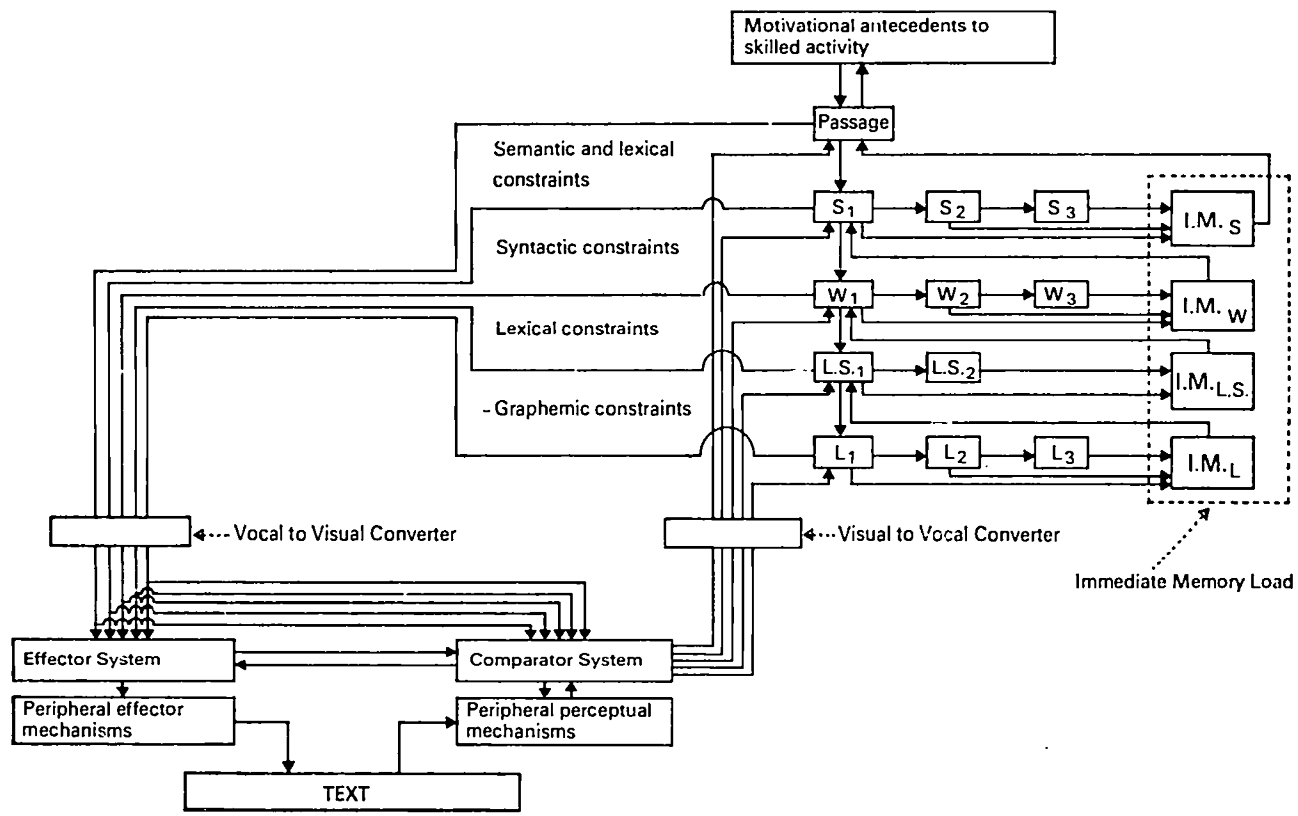


Fig. 1. Schematic representation of skilled reading behavior (Roberts & Lunzer, 1968, p. 203).

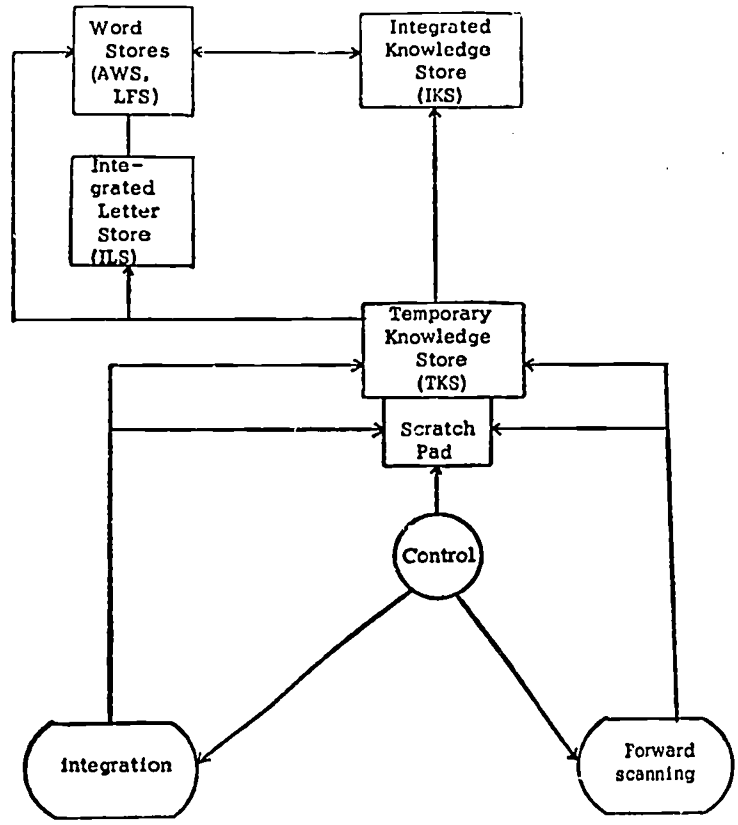


Fig. 2. Schematic diagram of the reading process (Venezky & Calfee, 1970, p. 277).

The overall structure of the Venezky and Calfee model, consists of three processes: forward scanning, integration, and comprehension. These processes are maintained by a flow of data from the temporary stores to the permanent stores (IKS, AWS, LFS). The stages function in a highly interdependent fashion and take place at an extremely rapid rate in the skilled reader. From the model, Venezky and Calfee infer the specific skills which must be acquired in learning to read and suggest a number of research questions concerning developmental aspects.

The Mackworth Model

Elsewhere in this report, J. Mackworth (1971) presented a model of the reading process which summarized and synthesized her extensive review of models related to the reading process and the psychological and neurological research underlying them (to which she is an important contributor). This model undoubtedly represents the current consensus of expert opinion in a number of fields concerning the identification and operational characteristics of the information-processing systems involved in reading.

The model, presented schematically as Figure 3, details the systems that operate sequentially in processing the reading stimuli. The visual input, taking place during the fixational pause, is an active process involving selection, attention, expectancy, and prediction. During the resulting sensory visual trace, which lasts for approximately 250 msec., the information contained in the trace is processed in parallel prior to its destruction by the data from the next fixation. Recognition of the input occurs by matching it to memory traces in long-term memory so that the input is stabilized as the iconic image. The iconic store, with a temporal capacity of from one to two seconds, is capable of holding several inputs simultaneously, thus smoothing the further processing of multiple discrete inputs. From the iconic store, words are coded into short-term memory by motor speech programs which activate the matrix of sensory associations and verbal probabilities that give rise to verbal expectancies. Short-term memory has a temporal capacity of several seconds but a limited informational capacity. The information is finally stored in long-term memory, which is connected to all prior processing through feedback systems. The auditory pathway, also diagrammed, operates with the same short- and long-term memory systems and plays an important role in learning to read and a lesser role in skilled reading.

The Geyer Model

Although classified as a comprehensive model of the reading process by the reviewers, the model developed by the

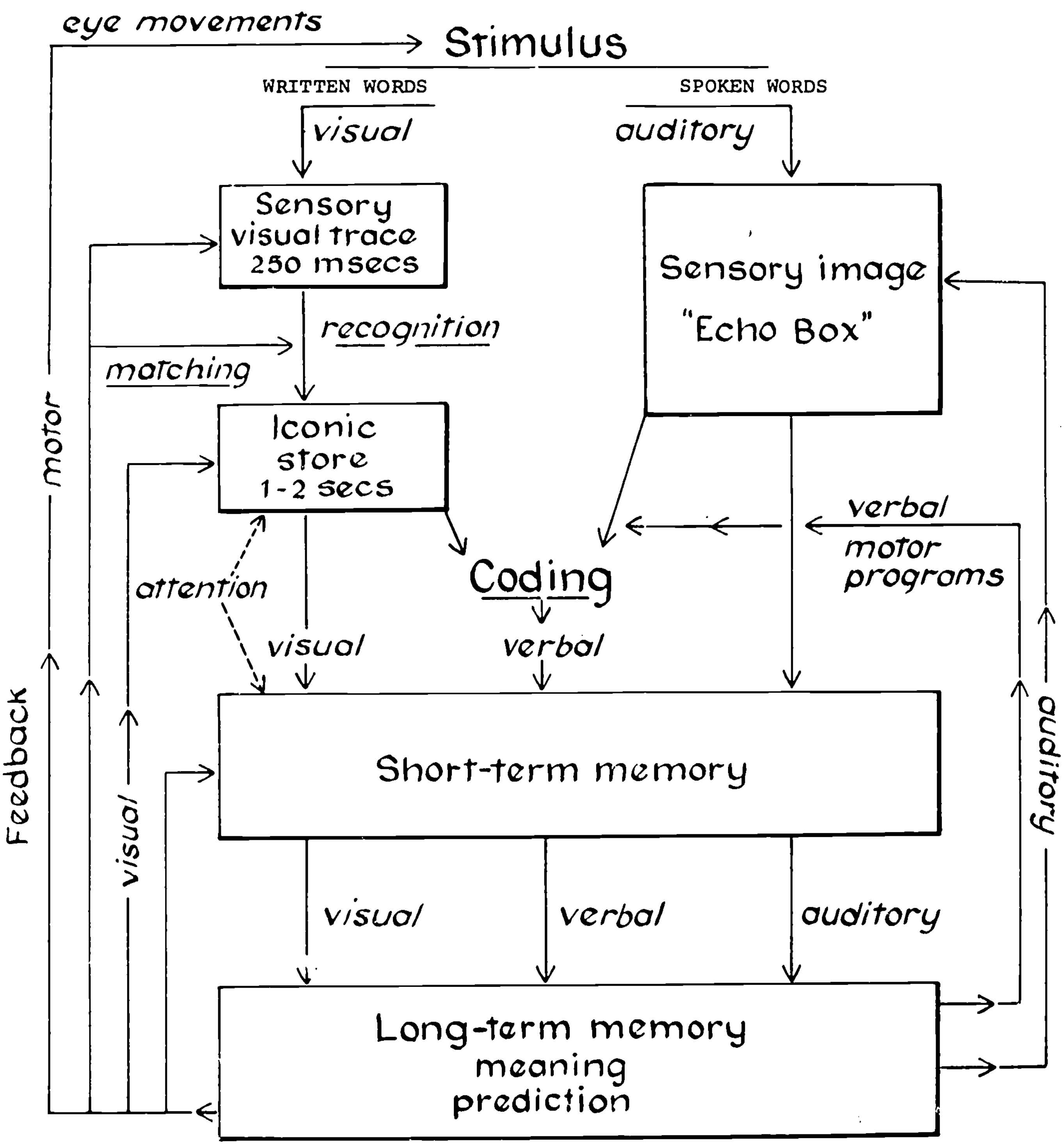


Fig. 3. Schematic model of the reading process (J. Mackworth, 1971, p. 8-74).

writer (Geyer, 1966, 1968, 1970) is delimited to those processing and storage systems hypothesized as functioning during the oral reading process between the moment in time when the stimulus is presented and when it is reported. The model views skilled ongoing reading as a multiple-stage process involving the temporal integration of the systems represented in Figure 4, each of which operates with differing temporal characteristics. The operations of long-term memory, feedback processes, and elements concerned with the processing of meaning were definitionally excluded from the model since the operational characteristics of these important systems had not been adequately delineated experimentally.

Analysis of the experimental literature on retinal locus effects, visual masking, and related visual phenomena forced a rejection of the classic common-sense assumption that all elements of the visual field are perceived simultaneously (Geyer, 1966, 1970). Consequently, the model hypothesized that the visual input specific to reading occurs sequentially at a rate of 8 msec. per letter space. In the tachistoscopic situation, this attentional scan takes place concurrently with the exposure (with appropriate lighting controls). In normal reading, the attentional scan would occur at any time within the fixational pause dependent upon the necessity to maintain a temporal steady state with the other systems. Following input, the information is coded into units and stored in an iconic store where it remains accessible for response for approximately one second. This store acts as a temporal buffer which allows smooth articulation between the very rapid input system and the internal response (naming) system that operates at the approximate rate of 250 msec. per unit. (It is the rate of operation of this system, undoubtedly through feedback, that enforces the well-known average pause length of 250 msec. It is the published opinion of the writer that the "visual-image" phenomenon demonstrated by Sperling (1960), and often cited as evidence for a visual "sensory register" of 250 msec., was an artifact of his tachistoscopic lighting procedures and is not applicable to normal reading). Following the internal response, a second storage system is available to act as a temporal buffer between internal and external response systems.

The model can be differentiated into three processing systems associated with sensory, recognitional, and motor processes. Interspersed among the three systems are two short-term storage systems which make smooth information processing possible by acting as temporal buffers for the differing operational rates of the processing systems. The model is capable of "explaining" a number of experimental phenomena and of extending them to the ongoing processes of normal reading. In normal skilled reading, the effective rate of reading would be a function of the rate of processing of the slowest system, all other systems maintaining a temporal steady state through

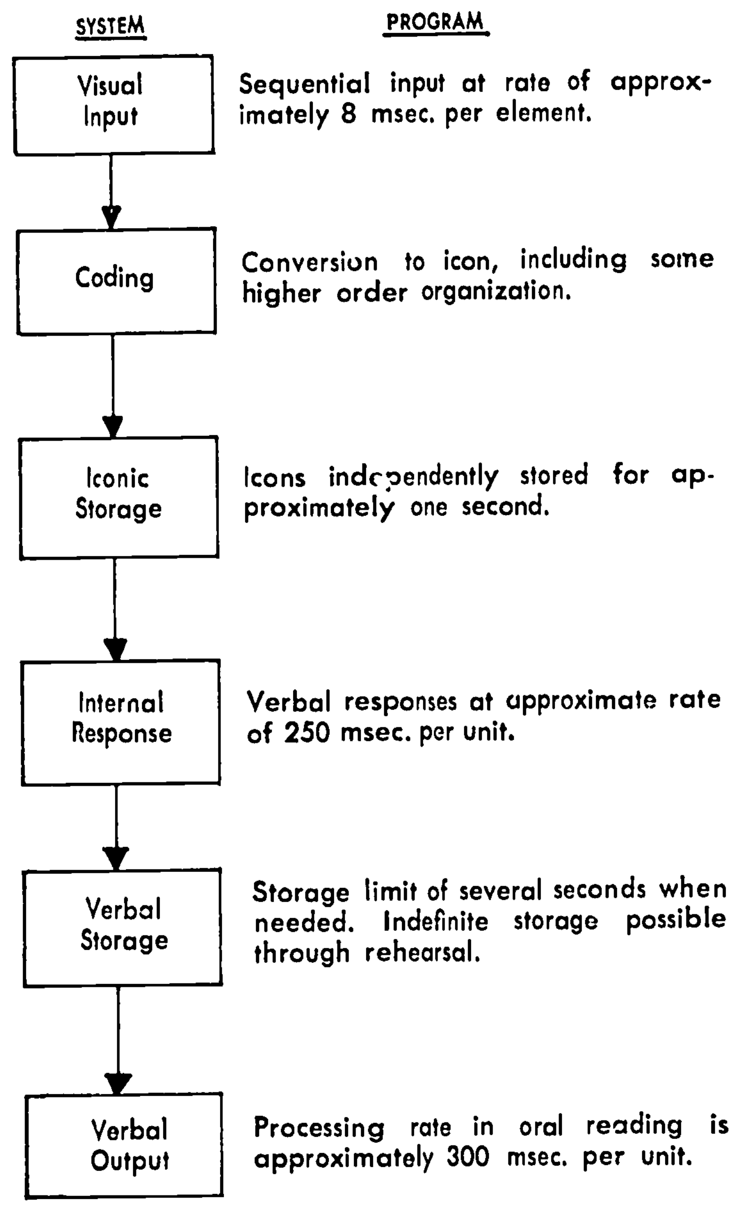


Fig. 4. Schematic model of perceptual processes in reading (Geyer, 1970, p. 76).

the actions of the two buffer stores. From this model a large number of implications for the teaching of reading could no doubt be drawn; but since much of the model has not enjoyed empirical verification, to draw such implications does not seem appropriate.

The Goodman Model

The model of the reading process advanced by Goodman (1971) is based on the premise that reading is not the precise, detailed, sequential perception of letters, words, and large language units that it is commonly held to be. Rather, reading is a selective process which

> . . . involves partial use of available minimal language cues selected from perceptual input on the basis of the reader's expectations. As this partial information is processed, tentative decisions are made to be confirmed, rejected, or refined as reading progresses [Goodman, 1970, p. 260].

As the title of the article states, reading is a "psycholinguistic guessing game."

Figure 5 presents Goodman's model in the form of a flow chart of the decision processes and related activities involved in the reading process. Goodman's description of these activities, in slightly edited form, follows:

> (1) The reader scans along a line of print from left to right and down the page, line by line. (2) He fixes at a point to permit eye focus. Some print will be central and in focus; some will be peripheral. Perhaps his perceptual field is a flattened circle. (3) Now begins the selection process. He picks up graphic cues, guided by constraints set up through prior choices, his language knowledge, his cognitive styles, and strategies he has learned. (4) He forms a perceptual image using these cues and his anticipated cues. This image is partly what he sees and partly what he expected to see. (5) Now he searches his memory for related syntactic, semantic, and phonological cues. This may lead to selection of more graphic cues and to reforming the perceptual image. (6) At this point, he makes a guess or tentative choice consistent with graphic cues. Semantic analysis leads to a partial decoding as far as possible. This meaning is stored in short-term memory as he proceeds. (7) If no guess is possible, he checks the recalled perceptual input and tries again. If a guess is still not possible, he takes another look at the text to gather more graphic cues. (8) If he can make a decodable choice, he tests it for semantic and grammatical acceptability in

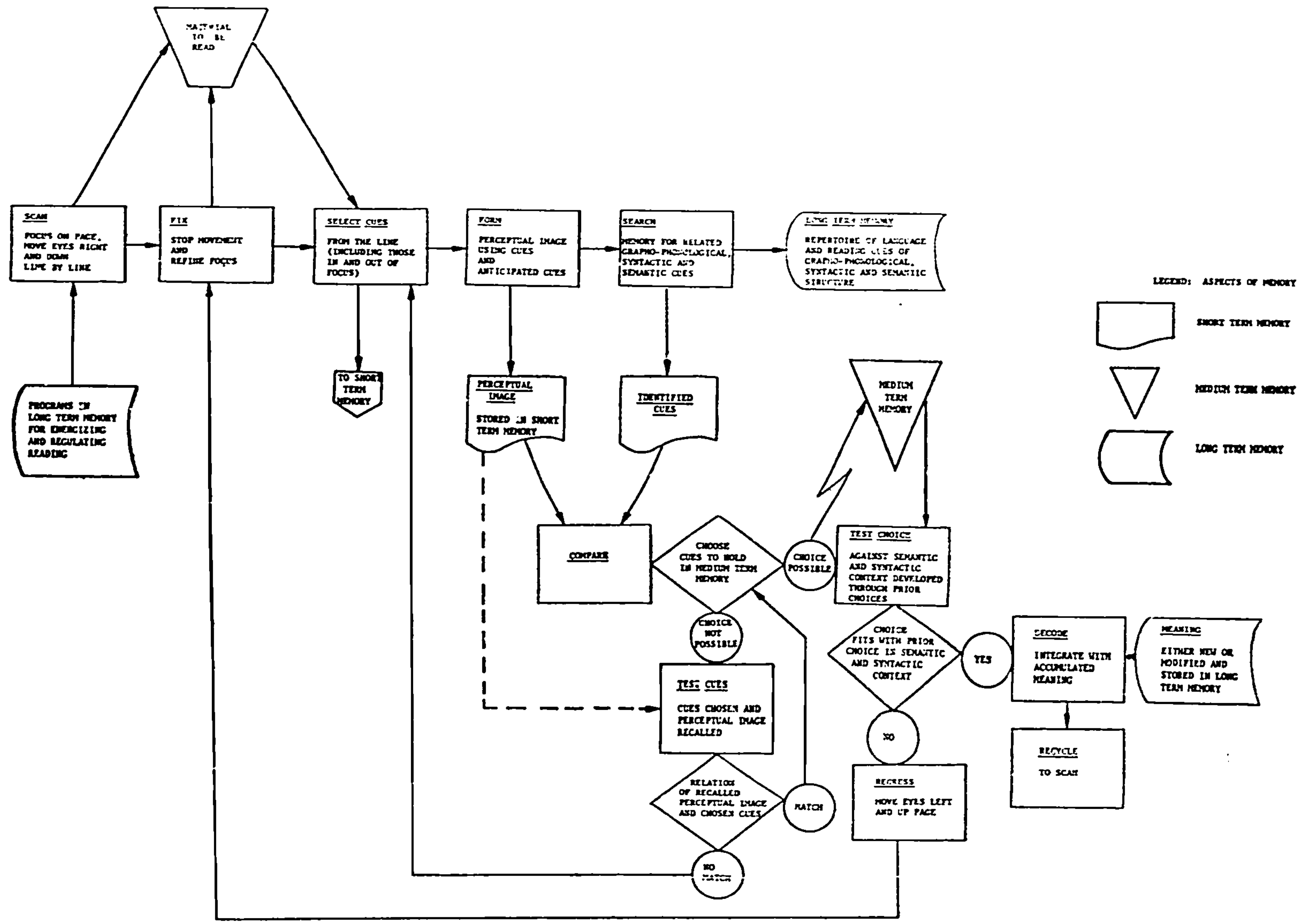


Fig. 5. Flow chart of model of reading process (Goodman, 1970, p. 272).

> the context developed by prior choices and decoding. (9) If the tentative choice is not acceptable semantically or syntactically, he regresses, scanning from right to left along the line and up the page to locate a point of semantic or syntactic inconsistency. When such a point is found, he starts over at that point. If no inconsistency can be identified, he reads on, seeking some cue which will make it possible to reconcile the anomalous situation. (10) If the choice is acceptable, decoding is extended, meaning is assimilated with prior meaning, and prior meaning is accommodated, if necessary. Expectations are formed about input and about meaning that lies ahead. (11) Then the cycle continues [Goodman, 1970, pp. 269-270, slightly edited].

While Goodman's model includes references to visual and memorial activities, primary emphasis is on the psycholinguistic steps of the decoding process. He cautions that these steps do not necessarily occur in the sequential or stretched-out form represented in the flow chart. Throughout, the model emphasizes the active search process manifested in an interaction between thought and language.

The Hochberg Model

It is unlikely that the senior author of the article by Hochberg and Brooks (1970) intended it to present a comprehensive model of the reading process (as it is classified by the reviewer). Yet the point of view and analyses presented in this article and elsewhere (Hochberg, 1970a, 1970b, 1970c) were judged of sufficient importance to warrant inclusion within this category. Hochberg's central point is that reading does not consist of automatic responses to an array or sequence of patterned stimuli. For reading to occur, the reader must <u>intend</u> to read the display and he must "pay attention" to its meaning. It is the factor of intention which accounts for the wide range of behaviors possible within the very general term "reading," behaviors ranging from proofreading to "skimming," and involving differing visual search patterns and performances.

While "intention" in reading has not been subjected to much experimental research, the processes of selective attention have been studied extensively in other contexts and modalities. Hochberg rejects the notion that selective attention is the result of a "filter" that passes signals presented on one channel while alternating or blocking other channels. He suggests a process of "analysis of synthesis" where attending to speech rests upon successive samplings and extrapolations of redundant trains of sound. He believes a similar hypothesis-testing procedure occurs in reading.

In reading, the reader is normally processing a text that is redundant in many ways. He need not see every part of every letter or word in order to understand the text or to guess at what is vaguely seen in peripheral vision. Through a knowledge of the redundancies of spelling, grammar, and the idiom of the text, the skilled reader can anticipate the message and therefore requires fewer fixations. These factors in the determination of fixation are called CSG for cognitive search guidance. The reader, in addition, makes use of information given in peripheral vision, as modified by linguistic expectancies. These determinants of fixation are called PSG, for peripheral search guidance. The experienced reader moves his eyes under the combined control of CSG and PSG, making a series of successive extrapolations and not processing information letter by letter.

The Crosby Model

Crosby and Liston (1968) presented a model of the reading process based on a definition of reading as a translation of graphic symbols into sound according to a recognized system. As a neurologist concerned with diagnosing dyslexia, the senior author differentiates between reading, as so defined, and comprehension of what is read. He believes that these processes are mediated by differing brain functions. A child learning to read must make use of existing neurological abilities, but as facility increases some of the function may be eliminated. This process takes place on three levels, each of which is illustrated by a schematic representation. Figures 6, 7, and 8 illustrate the neurological functions of the three levels of reading. The authors' description of the process follows:

> The image on the page is picked up by the eyes and transferred to the visual areas in the brain. Then, in visual perception the individual letters are distinguished from all other marks. Next, the reading function occurs, in which the child recognizes that which he has perceived to be a word and compares it to other known word images to identify it. At this point he says the word aloud, going through the functions of motor-speech. He then hears himself say the word and makes use of his long-established ability to hear, recognize, and comprehend the spoken word [Crosby & Liston, 1968, p. 46].
>
> [Figure 7] is the second level of reading used by most individuals all of the time and all individuals some of the time. In this diagram we are trying to convey the fact that the person eliminates the mechanics of motor-speech. He no longer says the word aloud and hears himself say it, although vibrations may be set up in his larynx and some portions of the mechanics of speech take

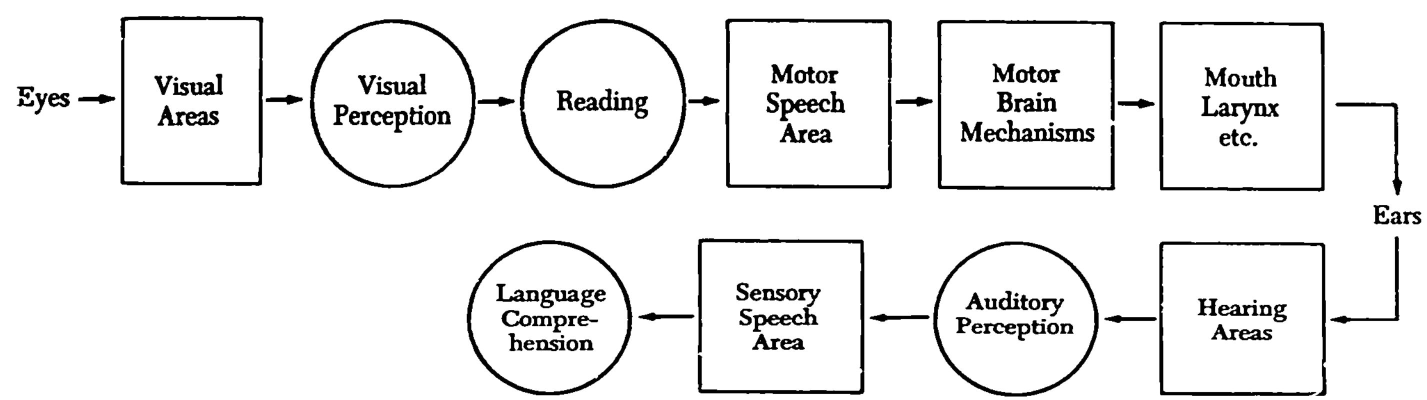


Fig. 6. Schematic representation of first-level reading (Crosby & Liston, 1968, p. 46).

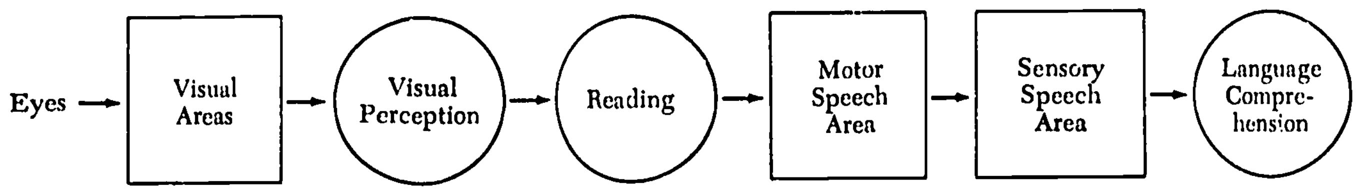


Fig. 7. Schematic representation of second-level reading (Crosby & Liston, 1968, p. 47).

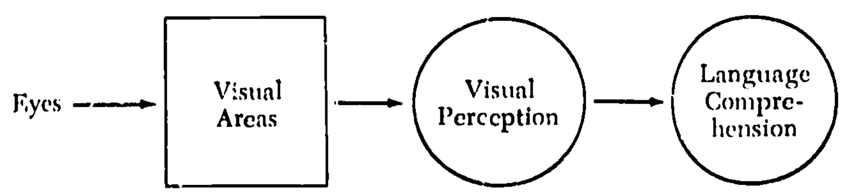


Fig. 8. Schematic representation of third-level reading (Crosby & Liston, 1968, p. 48).

> place. But certainly the brain function of motor-speech occurs. He goes through the mental process of saying the word without actually uttering it, and similarly he uses the hearing or sensory-speech function without using his ears and temporal cortex to reach language comprehension [Crosby & Liston, 1968, p. 47].
>
> The third level of reading reached by a small minority of rapid readers is shown in [Figure 8]. Here the person goes directly from visual perception to language comprehension, omitting any reference to the sound of the word. A new pathway to language comprehension has been established which permits rapid reading for meaning [Crosby & Liston, 1968, p. 48].

Crosby and Liston present several additional diagrams detailing the neurological processes involved in such tasks as reading without comprehension, writing from dictation, copying a known or unknown language, etc. These models are used as a basis for an extensive discussion of the diagnosis and treatment of dyslexia.

COMPREHENSIVE MODELS OF PROCESSES RELATED TO READING

This section presents models that the reviewers classified as comprehensive but which were not constructed specifically to represent the reading process. Included are models of general or visual information processing, models of components of the reading process, such as word perception, visual strategies, etc., and models of components with less specifically known relationships to reading, such as semantic memory. All come from the general field of psychology and most employ an information-processing approach.

Models of General Information Processing

Filter Theory

One of the most seminal works in the field of psychology in recent years is Perception and Communication by Broadbent (1958). In this book, Broadbent detailed his ideas concerning selective attention and information flow in the human observer. Figure 9 presents a schematic representation of this early general-processing model. In this model, Broadbent assumes that information is continually being received by the organism over a number of different input channels. These channels all impinge upon a selection system that operates as a filter, allowing only the most relevant signals to pass. Blocked signals are held briefly in short-term store (not shown in the figure). Signals accepted by the filter are

passed to a single decision channel of limited capacity. These signals are referred to information in a long-term memory store and appropriate responses are produced.

Broadbent's Filter Theory has generated a large amount of research activity, extending or questioning various components and operations. An important revision was suggested by Triesman (1964), who concluded that the filter may serve to attenuate or modulate the information content of a filtered channel rather than to block it completely as originally proposed. Under these conditions, filtered stimuli could still be responded to at some minimal level if the attenuation were mild or if the stimuli were preemptive. Most of the research activity surrounding Filter Theory has utilized the auditory modality.

The Sperling Models

Sperling has contributed a developmental sequence of models describing visual-information processing (Sperling, 1967, 1970) and auditory-information processing [Sperling & Speelman, 1970). In addition, his prolific research has contributed importantly to the models of others. Figure 10 presents the schematic representation of Sperling's 1967 model (Sperling, 1967). The components of the model include a visual-information store (VIS) that receives and briefly stores the visual information and a scan component that determines within a limited range the sequence of locations from which information is entered into the recognition buffer-memory (R-Buffer), which converts the visual image (e.g., of a letter) into a "program of motor-instructions." Rehearsal of the converted information is accomplished by having the rehearsal component execute the motor-instruction program, which enters the information into auditory storage (AID) where it can be remembered temporarily. A feedback loop from AIS to SCAN allows continuing rehearsal of the auditory image until a response is elicited. The model is intended to represent the information processing engaged in by a subject asked to write letters presented tachistoscopically, but its generality to other similar situations is assumed.

Sperling (1970) expanded his model and discussed its relevance to reading. Figure 11 presents the expanded model. The most obvious addition to the 1970 model is a long-term memory component (LTM) associated with each of the active processing components. The LTM's associated with short-term memory components (STM) are single-modality visual memory, motor memory, and auditory memory; those associated with scanning and rehearsal components are intermodality memories representing such skills as knowing the name of a printed letter and knowing the sequence of motor events necessary to saying it. Also added to the model was an auditory scan component (A SCAN)

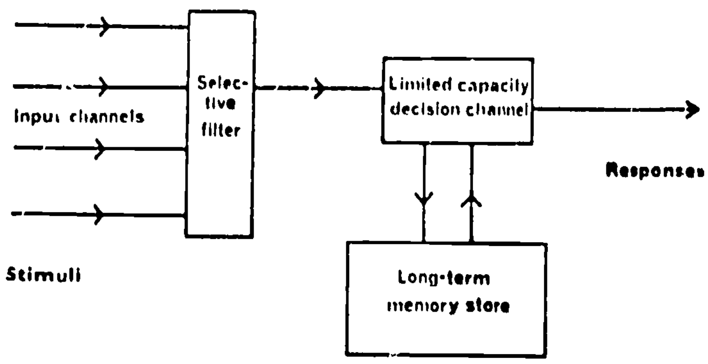


Fig. 9. Schematic model of selective attention and information flow (Broadbent, 1958, p. 299).

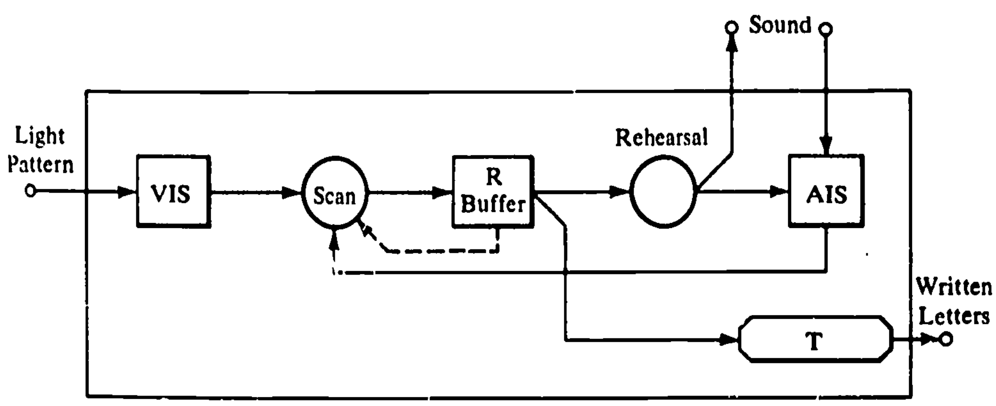


Fig. 10. Schematic representation of model of visual-information processing (Sperling, 1967, p. 290).

which feeds back to the recognition buffer-memory (RECOS STM) during auditory rehearsal. This activity was accomplished by the same scanning component that operated on visual material in the 1967 model, although auditory rehearsal is performed sequentially while visual "scanning" is a parallel process in the Sperling model.

Sperling (1970, p. 203) stated that the two aspects of the model that are of greatest relevance to reading are the visual-scan and auditory-memory components. His belief concerning the parallel nature of the visual scan was extended, and experimental evidence interpreted in support of this theoretical position was reported. The discussion, however, was concerned only with a post-exposural sequential scan, and the possibility of a rapid, serial input concurrent with the exposure (Geyer, 1966, 1968; Noton, 1970) was not considered. The experimental results presented fit either hypothesis. As Sperling noted, this is an issue of considerable importance to reading theory.

The Norman and Rumelhart Model

Figure 12 presents the schematic diagram of a model of perception and memory advanced by Norman and Rumelhart (1970). At the schematic and verbal level, the model resembles that of Sperling quite closely. It is intended as a general model representing both visual and auditory information processing. The physical signal is transformed into a sensory image by the sensory system and held briefly in a sensory storage system. A stimulus-analyzing mechanism extracts generalized features from the sensory image and presents them to the naming system. Following Sperling, the feature-extraction process is presumed to operate in parallel. The "vectors" of features are compared with relevant dictionary items and a match between vectors provides the stimulus name. The output of the naming dictionary is an ordered list of attributes, including the item name, which enters short-term memory. As more items enter STM, some of the attributes of the vectors are lost and retrieval is not always possible.

The model by Norman and Rumelhart is detailed in its description of processes. Proceeding from stated assumptions, the model is converted to mathematical terms under a variety of experimental conditions but is restricted to the use of simple, homogeneous lists of stimulus items. The mathematical model is then shown to fit existing data from a number of published experiments. The authors are scrupulous in crediting their theoretical debts. A major innovation claimed for their model is the naming system between perception and memory by which sensory images are transformed to memorial images.

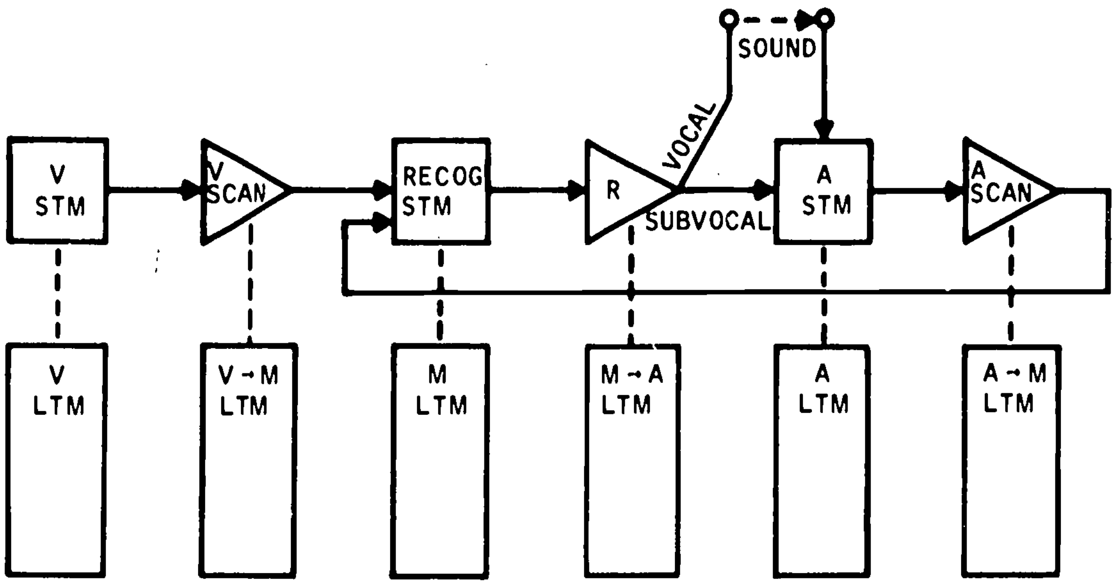


Fig. 11. Schematic representation of model of visual information processing (Sperling, 1970, p. 199).

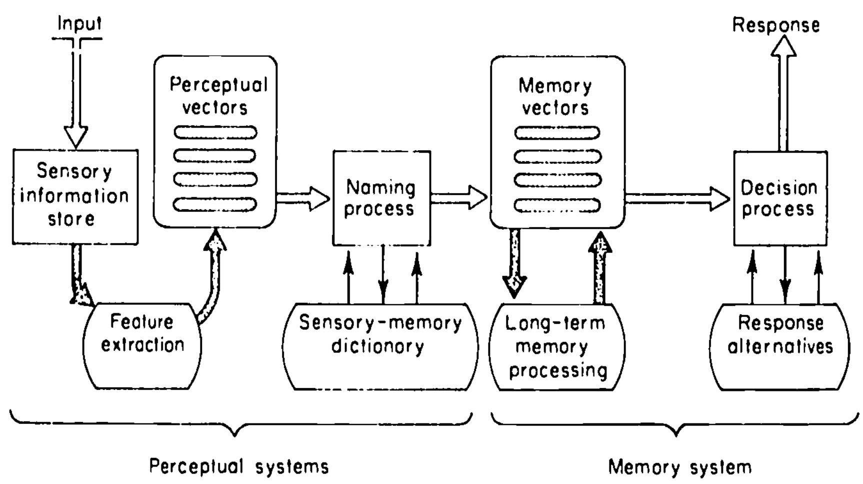


Fig. 12. Schematic representation of model for perception and memory (Norman & Rumelhart, 1970, p. 21).

The Biggs Model

The model presented by Biggs (1969) is intended as a general model of cognitive behavior applicable to broad areas of human functioning. The model is based on two main principles of coding: receiving the message in its informational entirety and transforming it into maximally economical units for operation and storage. The first of these principles is the task of a receptivity component which maintains the system in an input-receiving state. Economy-making strategies discussed are superordination, coding width, coding flexibility, speed of closure, and omission of information.

A flow diagram (Figure 13) utilizes the major concepts of the model to chart the possible progress of cognitive events. Input is received via the polysensory system and, on its way to the information-processing centers, stimulates the receptivity program (1). Following stimulation of the receptivity program, a "precode" (2) is made of input according to a criterion of importance determined by the prevailing need state. This precode classifies the input as relevant (3) or not relevant (13). Relevant stimuli are matched (4) with contents of the code store (5) which determines whether recoding is necessary (7, 10). In addition, a boost is fed back to the receptivity program from this stage. Further processing decisions and operations can lead to integration of the stimulus with long-term store or to some response output system, or to both implications of the model to learning and other psychological functions are discussed.

Computer Simulation Models of Information Processing

Hunt's Distributed Memory Model

Hunt (1971) presented a model whose purpose is "the ambitious and impossible task of describing a computing system which thinks like a man [p. 57]." Figure 14 presents a diagram of the general model. The central component is a long-term memory (LTM) which stores information permanently. Surrounding this component are a number of input channels containing buffer memories connected in series, and a central computing device that monitors the channels. The central computing system contains a short-term memory (STM) component that stores an exact memory of very recently received input and an intermediate-term memory component (ITM), which stores a general memory of stimuli received over a longer but still brief period. All systems may draw on the information stored in LTM, but only ITM has the capability of coding data for entry to LTM.

Sensory buffers, which make contact with the environment, are composed of transducers, a memory unit, and a

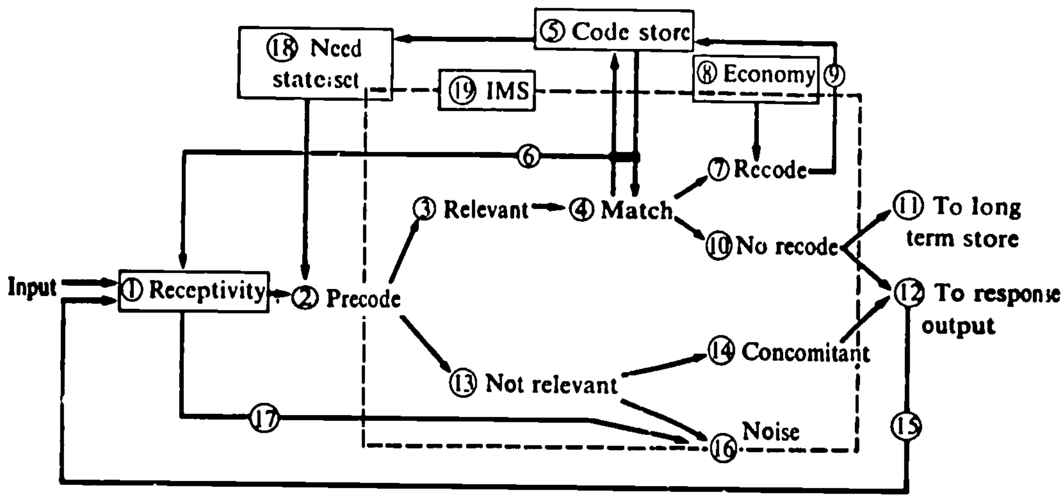


Fig. 13. Flow diagram of possible cognitive progress (Biggs, 1969, p. 293).

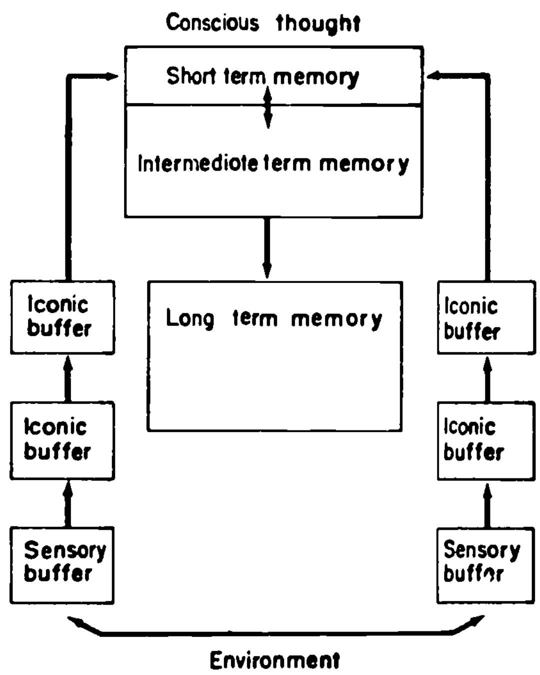


Fig. 14. General diagram of the distributed-memory model (Hunt, 1971, p. 59).

feature-detection unit. The feature detectors categorize stimuli into "probably meaningful" units for further analysis in the intermediate buffers. Intermediate buffers consist of a memory register, a processing unit, and an addressing unit. These units work together with LTM in further analyzing the output of the sensory buffers in order to deliver a recognized stimulus situation to conscious memory. Recognizable items pass through STM and are incorporated into a general record located in ITM. Programs for combining and interpreting the flow of information to ITM are stored in LTM. The operations of the Distributed Memory Model in such processing as verbal comprehension, problem solving, concept identification, etc., are extensively discussed.

The EPAM Model

EPAM (Elementary Perceiver and Memorizer) is a computer-simulation model of cognitive processes developed by Feigenbaum (1970). The model holds as primitive postulates that information processing is essentially serial in nature and that it takes time to perform. Three types of information storage structures are postulated. A buffer storage mechanism (immediate memory) holds input from peripheral sensing and encoding mechanisms in a state of availability for further central processing. It is of extremely small size and provides the only channel of communication between the central processes and the sensing processes at the periphery. The acquisition memory is a large working memory for discrimination and familiarization processes. The information necessary to discriminate among learned objects is stored in this memory. The permanent store is a long-term repository of images linked together in a highly interconnected web of cross associations.

The model is detailed in describing the operations of the various components and contains a number of hypotheses about memory-processing activity. At the level of the acquisition memory, a matching process scans stimulus encodings and images serially controlled by a noticing order, an adaptive strategy for focusing attention. Image building consists of the orderly assembling of cue-tokens in the acquisition memory. Cue-tokens reference other images in the net. The discrimination net of the acquisition memory becomes elaborated in a wholly pragmatic manner, its growth reflecting what is just adequate for correct performance at any stage. A process transfers images, discrimination information, and perhaps even subnets of the acquisition memory to the permanent store. The transferred information is reorganized and tied into the web structure of the permanent store according to an organizational scheme which is more logical and less pragmatic than that of the acquisition memory.

The Reitman Model

Figure 15 presents a model of information processing proposed by Reitman (1970). The major concern of the model is with the structure and timing of the memory systems rather than with the details of the processing mechanisms. Items enter the system through the senses and are stored in a sensory register for a fraction of a second. Items in sensory storage are subject to very rapid decay and are lost if not passed on to the recognizing mechanism which for verbal materials is a naming mechanism. Once named, items line up to be coded. Coding is done in the working memory which has access to relevant information from long-term memory. At the end of the task a reorganizing process disassembles the working memory and the significant parts are stored in long-term memory.

The diagram and associated verbal description served as a framework for the development of a more formal model specified in sufficient detail for computer programming. The program considers behavior in the single case of a single query, constant coding time, linear decay, and a first-in, first-out priority basis. A number of variables such as the processing rate of each component, the time required to process an item, processing priorities, etc., are under the control of the experimenter. The model has been tested against existing data.

Models of Visual Pattern Perception

The Noton Model

Noton (1970) presented a theory of visual pattern perception intended to model three aspects: (a) how patterns are learned, (b) how patterns are recognized when subsequently encountered, and (c) how patterns are recognized under unfavorable conditions of distortion, rotation, visual noise, etc. Learning to recognize a pattern is assumed to be a process of constructing an internal representation that matches the pattern. The internal representation consists of networks of memory traces which record both the features of the pattern and the attentional shifts required to pass from feature to feature across the visual field. Attentional shifts may take the form of saccadic eye movements when large angular displacements are involved or they may be carried out internally without moving the eye, the center of attention simply being shifted to a new area of the visual field in the case of small angular displacements. Shifts of visual attention are considered to be a form of motor activity whether or not eye movements are involved.

Recognizing a pattern is the process of finding in the memory system a feature network which matches the pattern,

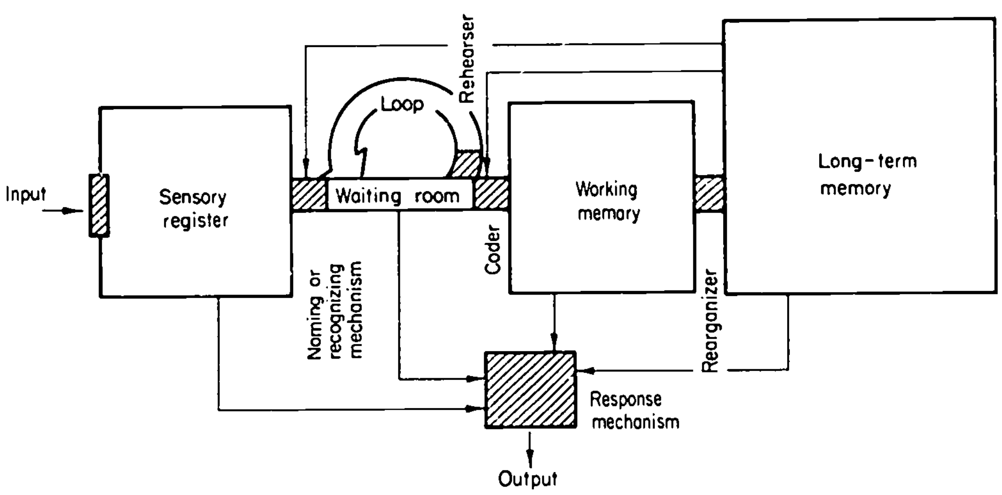


Fig. 15. Schematic diagram of information-processing model (Reitman, 1970, p. 118).

> the matching being carried out sequentially, feature by feature. When a pattern appears in the visual field, attention is first directed at random to some feature of the pattern. This feature activates corresponding sensory memory traces in one or more feature networks, potential matches for the pattern, and one of these networks is arbitrarily selected for matching. The recognition system now attempts to match feature network and pattern, by executing a sequence of attention shifts specified by the network and verifying the successive features called for by the network. . . . It is important to note that the feature network guides the matching process, directing attention from feature to feature of the pattern [p. 351].

In the case of very complex patterns, Noton suggests that feature networks may be organized on multiple levels. Upper-level networks record overall impressions of patterns that are subdivided into less complex subpatterns. Lower-level networks contain the details of features. Thus the organism is equipped with ". . . a complete hierarchically organized model of its environment, the feature networks of the present theory being simply the lowest level of this hierarchy [p. 353]."

The Gibson Models

The important contributions of Gibson and her coworkers (Gibson, 1970a, 1970b; Gibson, Gibson, Pick, & Osser, 1962; Gibson, Osser, & Pick, 1963; Gibson, Osser, Schiff, & Smith, 1970; Gibson, Pick, Osser, & Hammond, 1962) have been extensively described in several papers in this report (e.g., Wanat, 1971; Williams, 1971) and will be briefly summarized here. Through developmental studies of how children learn to discriminate letters and letter-like forms, Gibson and her coworkers postulated a set of "rules" that describe the construction of letters and a set of distinctive features that compose grapheme patterns. Children improve in their ability to discriminate letter-like forms as a result of two processes: (a) learning to detect the invariant and, therefore, distinctive features of the forms and (b) becoming more sensitive to these features. Discrimination among letters is a function of the number of feature differences among the letters, which differ in the number of features they contain. Confusability of letters is related to this fact. The reader brings to the task a hierarchically arranged knowledge of feature patterns.

At the level of letter combinations, important linguistic units consist of combinations of letters having invariant spelling-to-sound correlations. Thus, the learning of the rules of grapheme-phoneme correspondences is more closely related to concept formation than to simple association

learning. While no single relationship exists between single letters and sounds in English, higher-order rules governing the pronunciation of letter combinations are stable and these constitute the functional graphic unit. Gibson (1970b) has combined these elements of the reading process into a comprehensive statement of how children learn to read, which is discussed elsewhere in this report.

The Posner Model

Posner and his coworkers (Posner, 1968; Posner, Boies, Eichelman, & Taylor, 1969) have detailed the levels of processing and associated processes involved in visual perception. The model proceeds from the stimulus through the abstract idea (from name to rule); in generation, the flow is in the opposite direction. The levels are not necessarily joined by obligatory transformations and the construction of a code at one level does not obliterate previous codes. Codes are separately stored, have their own time courses, and can be interrogated independently. Both visual and name records are stored in long-term memory, but visual records are not stored in detail for every visual object; instead visual objects are combined and summarized.

Perceptual and memory codes in visual perception are complex and only a detailed account of their structure within a particular task can provide reasonable answers to questions concerning the effects of some variable on the perceptual process. Following an exposure, subjects have access to visual information. The rate of decay of this information is dependent upon where the attention is focused. Under conditions where subjects have name information available (as in reading), visual information decays rapidly as subjects attend to the name information. Visual information is retained where subjects attend to visual aspects, but this information is not consolidated, as is name information through rehearsal.

Model of Speech Perception

The Liberman Model

Liberman et al. (1967) presented an analysis of the speech code which shows that many phonemes are encoded so a single acoustic cue can carry information in parallel about successive phonemic segments. This reduces the rate at which discrete sounds must be perceived but at the price of a complex relationship between cue and phoneme. Cues vary greatly with context and there are, in these cases, no commutable acoustic segments of phonemic size. For these reasons, the perception of speech is a more complex task than reading; yet it is more easily learned. It is likely that phoneme

perception requires a special decoder, and the model proposes that the encoding occurs below the level of the invariant neuromotor commands to the articulatory muscles. The decoder may then identify phonemes by referring incoming speech sounds to those commands.

In the production of speech, the thought sentence is converted into phonemes in the CNS and then passed to the muscles by neuromotor rules. These commands produce muscle contractions while articulatory rules determine the place and manner of the vocal-tract activity. Finally, acoustic rules transform the speech into speech sounds. Perception of speech must utilize part of the same system; it is not a simple matching task.

Models of Memory Retrieval

The Collins and Quillian Model

Collins and Quillian (1970) used reaction times to study two possible models of long-term semantic memory. One model holds that each item stored in long-term memory includes all the associations of that item. The other holds that items are stored separately from generalizations about items and must be inferentially linked at recall. Experimental findings favored the second of these two, called the spreading-activation model.

In the spreading-activation model (which has been programmed for computer simulation), only a few attributes are stored with the mental representation or name of an object. Other possible attributes are stored as generalizations relating to the class to which the object belongs. The object carries pointers towards the various classes to which it might belong. The program moves each pointer along from the starting nodes, leaving tags at each node. Whenever a tag from another node is discovered, an intersection is found that traces a path back to the relevant starting nodes. Each node reached in the intersection process is facilitated. Prediction from the model involves the facilitation found at nodes on and off the path.

The Meyer Model

On the basis of reaction-time experiments, Meyer (1970) rejected five plausible one-stage models of semantic memory and suggested a two-stage model. The model assumes a hierarchical organization of memory. Stage 1 is used for deciding whether categories are related. If they are related, Stage 2 is used for determining how. The experiments reported detail many of the operations involved in making true-false

decisions concerning statements of the general forms: "All S are P" or "Some S are P." The model suggests the interesting possibility that subsets and supersets which seem to be produced from memory may instead be "computed" from other types of information that are stored. In addition, certain types of stored acoustic memory may not be directly accessible but must be accessed through other information.

Bernbach's Replica Model

Bernbach (1969, 1970) holds that the postulating of separate postperceptual short-term memory units is a retreat from parsimony that is not required by the data. As an alternative, he has outlined a replica model, which can account for many of the phenomena that often serve as evidence for short-term memory. The model is specifically concerned with the retention of items which have been presented for a period long enough so that their perception and coding is assured. It is not concerned with perceptual stores, response processes, or the effects of structure. Thus, the model is intended to deal with short-term retention and the learning of independent units like nonsense syllables, paired-associates, and so on.

The replica model assumes that when an item is presented, an internal representation of it (called a replica) is stored in memory. Between item presentations, the subject rehearses the most recent item, adding additional replicas to the store. Rehearsal of the most recently presented item is followed by general rehearsals of all items presented that have not yet been forgotten. With each general rehearsal, one additional replica of the items rehearsed gets stored. When a new item is presented, any or all of the other items may lose exactly one replica. At the time that the subject's memory is tested, it is assumed that he will perform perfectly as long as he retains at least one replica of the item tested. The model developed from these assumptions has been shown to be compatible with data from a variety of experiments.

PARTIAL MODELS OF PROCESSES RELATED TO READING

The models classified by the reviewers as partial models cover the general topics and use the approaches found in the comprehensive models reviewed above. In addition, models from the field of neuropsychology and two psychometric models of reading comprehension are included. In some instances, partial models attempt to detail the processes that make up components of the comprehensive models. In other cases, a partial model may attempt to delineate only certain aspects of a phenomenon. Distinctions between "partial" and "comprehensive," however, tend to be relative and may be influenced

by the point of view from which the model is approached. Thus, many of the models in this section could be considered comprehensive models of something that is part of a larger phenomenon, but which, in itself, is made up of smaller subparts.

Models of Perceptual Processing

The Harcum Model

Harcum (1967) reviewed the literature relating to the long-noted similarity between results obtained in serial-learning and tachistoscopic pattern-perception experiments. He concluded that the similarity exists because the "perceptual" and "learning" tasks involve similar psychological processes--that each observation in perception is a miniature task in serial learning. The major basic components of the process are (a) element differentiation, (b) selective analysis, and (c) mnemonic organization. These components are not discrete, but are major interconnected parts of the complete multifarious process, a process whose overall purpose is to translate the information in a sensory input into a language appropriate to the required response system. When arranged on a gross time dimension, the translation process occurs in the following stages: (t_1), stimulus presentation; (t_2), element differentiation; (t_3), intrinsic organization; (t_4), selection; (t_5), codification; and (t_6), response selection. Variables affecting each stage are suggested and possible feedback processes are indicated.

The Cohen Model

Cohen (1969) presented a model of letter recognition developed from his experimental evidence showing parallel visual and acoustic processing. In this model, each stimulus receives visual identification and a name identification, both of which are stored separately in short-term memory. A two-way comparison is possible between the memory traces. This parallel processing allows immediate recognition of errors and avoids confusability in either mode. The model may be of limited generality since subjects may emphasize the more useful modality in a normal situation. Also, it is probable that in a situation requiring matching multidimensional stimuli, multiple comparisons would be required.

The Morton Model

Morton (1969) and Morton and Broadbent (1967) developed a model of word perception having as its central unit a hypothetical device termed a logogen. The logogen accepts information from the sensory-analysis mechanisms concerning

the properties of linguistic stimuli. It also accepts information from context-producing mechanisms. When a certain amount of information has been accumulated by the logogen, a response is made available; that is, a representation of the appropriate motor sequence is stored in immediate memory. Incoming information has only a numerical effect upon any logogen, which counts the number of members of its defining sets that occur. When the count rises above a threshold value, the corresponding response is made available. Available responses go to the Output Buffer or are recirculated to the Logogen System in a rehearsal loop. The Logogen System is passive in operation but other components of the total system may be active. It is connected to the Output Buffer through a single channel. The Output Buffer is seen as the source of the eye-voice span in reading. The model has been detailed sufficiently for quantification. Quantitative predictions have been generated with which the obtained data were not inconsistent.

The Wheeler Models

Wheeler (1970) proposed five alternative hypotheses to account for the finding that, with letter redundancies controlled, recognition of a letter is more accurate in the context of a word than recognition of a letter by itself or in a series of unrelated letters. On the basis of experimental findings, Wheeler rejected all five hypotheses as complete explanations. He suggested three possible models that could account for the results. The first model assumes that interaction between letters provides more features than the letters independently, but this model would require a frequency assumption to account for the failure of quadrigrams to produce superior perception. The second model assumes that in the perception of words, certain features are more important than others. In this case, the feature-extraction process could be selective with word stimuli such that, of the features extracted for a given exposure time, more would be germane to the choice between alternatives presented in the experimental procedure. These two models both assume some enhancement of the feature-extraction process in the perception of words. The third model proposes that information is lost in the case of single-letter stimuli, probably during the process of conversion of the feature information to name information. Some of this information would be supplied by the simultaneous constraints of all letter positions where words were the stimuli. This simultaneous-constraints model would operate at two stages. The first is a feature-extraction stage operating in parallel. The second stage uses the features to find, construct, or otherwise determine a code for the stimulus. A choice between these models could not be made from the experimental evidence. Wheeler suggested that the long-sought-for perceptual unit could be isolated through the

mutual facilitation effect. He felt that the data indicated that such units were larger than letters but were not necessarily words since the demonstrated word effect could be due to contained diagrams or other spelling patterns.

The Aderman and Smith Model

Aderman and Smith (in press) examined the role of expectancy in the determination of the functional unit in perceptual recognition. Their results supported both the hypothesis of Gibson, Pick, Osser, and Hammond (1962) that either letters or spelling patterns could serve as functional units and Neisser's (1967) hypothesis that S's expectancy determines which unit is used. Prior to perception, a decision is made as to how to segment letter strings. The decision may occur prior to seeing the string or it may be part of the preattentive process on presentation. The string is segmented into the largest possible units permitted by the expected organization that have representations in long-term memory. Such representations must include positional information since spelling patterns depend upon position.

The Hansen and Rodgers Model

Hansen and Rodgers (1965) postulated the "vocalic center group" (VCG) as the psycholinguistic unit for beginning readers and formulated a "heuristic algorithm" to specify the information flow that would simulate the initial reading performance. The VCG is the optimally minimal sequence within which all necessary rules of phonemic co-occurrence can be stated. It is an elementary structure resulting from the integration of phonemic elements into a minimal pronunciation unit. As such, it resembles the syllable, but it is defined over a set of phonotactic rules. A broad continuum of VCG forms is postulated, which ranges from "non-permissible" to "favored." The "heuristic algorithm" includes the processes of syllabification, orthographic to phonemic translation, VCG construction and concatenation, memory storage, and recognition-matching. A prediction that speech-recognition errors for given words would be monotonically related to initial reading errors on the same words was confirmed.

The Bryden Model

Bryden (1967) proposed a model for the sequential organization of behavior based on an analysis of the experimental literature on retinal locus effects in vision and dichotic listening experiments in audition. The model assumes that the presentation of a stimulus activates some kind of trace system corresponding to the stimulus. These traces have

specific spatial and temporal components. Identical stimuli presented from different spatial or temporal positions must either excite different traces or a common trace with added elements containing spatial or temporal information, or both. If a number of trace systems are active simultaneously, not all can lead to a response at the same time. The problem is one of determining how responses are ordered in a particular fashion. The model postulates a central organizing system operating between a stimulus trace and a central rehearsal system. The ordering systems control the general sequence of responding by a process of inhibition of elements. This process is sequentially released by the response to the immediately preceding element. At a later decision point, an additional control mechanism determines whether the output of the organizing system will be overt or retained as a covert rehearsal. The model is shown to apply to a variety of experimental situations where the major task is the translation of spatial information to temporal sequences or the reverse.

The Elkind Point of View

Elkind (1969) presented a theoretical paper on figurative perception based on Piagetian theory of perceptual development. Although it does not present a model in any usual sense, the paper was included as a theoretical point of view of considerable importance in understanding perceptual phenomena. The growth of figurative perception is characterized by a transition from a process that is relatively static and stable to one that is active and dynamic. With increasing age, the child is better able to reverse figure and ground, to integrate parts and wholes, and to scan configurations in more systematic and novel ways. Early perception is characterized by molecular processes such as centration, where the response is to individual stimulus elements in the display. Elements centered upon tend to be overestimated, while the remaining elements are underestimated. As the child grows older, his perception is increasingly determined by higher-order perceptual and cognitive abilities and decreasingly determined by the Gestalt properties of the stimulus. Perceptual maturity is the attainment of a relative autonomy from the constraints of the field effects. At this stage, molar processes relate successive centrations across spatial or temporal distances. Implications of this theoretical position to reading and learning to read are discussed.

Models of Memory and Memory Processes

The Massa Model

Massa (1967) discussed the functional properties of a short-term visual memory (STVM) and presented a brief model of

this system. The major function of STVM is to "smooth" the flow of information to the higher centers of the brain from retinal images which change in response to saccadic movements. The STVM may accomplish this by providing the functional mechanisms which separate the signal detection and information perception aspects of vision. The model divides STVM into three components: (a) a read-in component which is instantaneous and eidetic, (b) a storage component which stores the input for .25 to 1.0 seconds--sufficiently long for holding a visual image between successive fixation points, and (c) a read-out component which scans the image at a rate of tens of milliseconds per English letter.

The Shiffrin and Atkinson Model

Shiffrin and Atkinson (1969) presented a model of memory with primary emphasis on the processes by which information is stored and retrieved in long-term memory. Three memory stores were postulated: the sensory register, the short-term store, and the long-term store. The sensory register is a very short-lived store decaying over a period of several hundred milliseconds in the visual modality. The short-term memory store may be either a separate system or a temporary activation of information stored in the long-term store. Information in the short-term store will be lost in about 30 seconds if not attended to, but control processes such as rehearsal can maintain information indefinitely. The long-term store is a permanent memory for information, but increasingly ineffective search of the stored material as new material is stored can result in forgetting and related phenomena. Storage and retrieval in the long-term store are parallel processes each of which is divided into three stages. Transfer, placement, and image-production are the primary mechanisms of storage and are paralleled by search, recovery, and response generation in the retrieval mode. Long-term store is self-addressing and storage locations vary from one ensemble of information to another. Each ensemble defines a number of memory areas in which storage is likely defined in terms of modality of the information, level of analysis, temporal dimensions, and similar relevant discussions. The extent of the memory search necessary for retrieval depends on the degree of specification of the storage information.

Wilson (1966) extended the Atkinson and Shiffrin model by postulating an information chunking and coding mechanism between the sensory register and short-term store and by describing a hierarchy of coding routines for the processing of verbal data. Under this model, the stimulus passes from the sensory register to a coding buffer which either passes it on to a memory buffer or matches it with information in long-term storage. With each coding sweep, the chunk is weighted to take into account the bits included in it. The

chunk may rise to include a whole phrase or even higher levels of information. Crowder (1970) extended the Atkinson and Shiffrin model by relating it to Morton's concept of the logogen. He believed the three levels of coding are the precategorical and postcategorical with the latter subdividing into rote memory and semantic memory. The three dynamic processes associated with the levels of coding are selective attention, rehearsal, and categorization.

The Waugh Model

Waugh (1970) discussed briefly a dual-trace model of short-term memory designed to describe the serial retention of well-defined verbal items. The model assumes that every serial item enters into a primary memory system which is limited to the most recent items attended to. Traces in this store do not decay with time, but are disrupted by items following. Serial items can be transferred to a larger, more stable store, called secondary memory. Items in this store neither decay with time nor are they disrupted by new items, but retrieval from this store is affected by positional and associational factors. Both of these memory systems are involved in short-term memory.

The Wickelgren Model

Wickelgren (1969, 1970) presented a complex theory of memory which analyzes memory into four components: very short-term memory, short-term memory, intermediate-term memory, and long-term memory. Each event and each association between two events is characterized by a vector of unidimensional strength for each of the four time traces and in each of an unknown number of modalities. Each trace in each modality passes through four phases: acquisition, consolidation, decay, and retrieval. The theory has been stated in quantitative terms and can account for many phenomena. The test event, however, must be sufficiently simple that S's treat it as a unit, making a single judgment concerning it. Therefore, the theory at present is not applicable to language processing.

The Cohen and Granström Model

Cohen and Granström (1968) studied the nature of short-term memory by varying the mode of response and type of material interpolated during a retention interval. They concluded that short-term reproductive memory is mainly verbal whereas short-term recognition memory is mainly nonverbal. Since the nonverbal type of memory does not exhibit the properties of a sensory visual trace, it is postulated as being a third type of store. Short-term reproductive memory is a more

active process involving rehearsal of the strong verbal component. Conrad (1970) tested deaf children and found evidence for differing coding bases for children with varying degrees of speech difficulties. The children who were above average in speech relied on articulatory coding while those deficient in speech used some other code such as shape. The articulation group showed the same confusion matrix patterns as normal subjects, while the matrices of the nonarticulatory children were different.

Psychometric Models of Reading Comprehension

An extensive literature exists in psychometric approaches to an understanding of reading comprehension. While factor analytic and related procedures do not yield models, as the results give no indication of operations, such studies can yield important evidence concerning the nature and structure of components and are, therefore, of interest in a modeling context. This literature was reviewed by F. B. Davis and is extensively discussed in his paper in this report (Davis, 1971).

The Chapman Models

Chapman (1969) suggested three possible models of comprehension in reading. These are (1) an independent-skill model holding that comprehension is the product of a set of independent skills, (2) a global-skill theory postulating comprehension as a unitary ability, and (3) a hierarchical-skills theory which postulates a hierarchical arrangement of correlated skills. Davis (1971) concluded that the evidence requires a multiple, correlated skills model which may or may not be hierarchically arranged.

Davis' Eight Skills

Davis (1941, 1968) has performed extensive analyses of reading comprehension and has identified eight skills used in comprehension by mature readers. These eight skills have been shown to be validly different through cross-validated uniqueness analysis. The postulated skills are (a) skill in recalling word meanings, (b) skill in inferring word meanings from context, (c) skill in finding answers to questions answered directly or in paraphrase, (d) skill in weaving ideas, (e) skill in drawing inferences from context, (f) skill in inferring the purpose, tone, and mood of the author, (g) skill in identifying author's literary techniques, and (h) skill in following the structure of a passage.

Neurological Models

The Pribram Model of Attention

Pribram (1970) outlined the brain mechanisms involved in attention and discussed the role of the intrinsic processing areas in actively regulating the ongoing processing of the sensory systems. The intrinsic processing areas are separated from the sensory areas by cortical areas which can be removed without affecting visual recognition or learning, but undercutting the areas drastically interferes with their functions. This evidence for cortico-subcortico connections calls into question the usual views of the functioning of the processing cortex. In addition, intersensory associations do not take place in the processing areas but seem to be effected in the primary sensory systems per se. The role of the intrinsic processing cortex is to effect identifications by activating attention. The frontal cortex produces a concentration of attention and the posterior cortex produces desynchronization and generalized attention.

> It is as if the sensory systems were fitted with a zoom lens: the frontal cortex provides a long focus which enlarges the item of interest and reduces depth of field; conversely, the posterior processing cortex provides a short focus which allows a much larger field to be sharply imaged [p. 159].

When the intrinsic processing cortex is damaged, ordinary perceptual operations necessary for tracking and responding to stimulus characteristics are not affected, but such damage does alter an active attentive process effected through efferent, corticofugal influences on the sensory systems.

The Pribram Model of Memory

Pribram (1969a, 1969b) presented a neurological model of memory which compares its operation with that of a hologram Memory functions through the four R's of representation, reconstruction, registration, and rearrangement. The brain is constructed to work with images. The incoming stimulus is represented in the brain by wave fronts that by interference effects carry the image and store it by modification of brain protein. While the neural hologram produces spatial encoding (representation), temporal encoding (registration) involves organization and rehearsal and, therefore, requires attention. Attention to one input involves inhibition of the neural responses to the others, thus segregating neural events. These processes of orientation and habituation arise from the corticofugal systems. Neural holograms are stored in ways that allow optimal reconstruction to occur to minimal information. Pribram suggests that the amplitude and phase angle of the

wave pattern are stored, each column of cells being tuned to a specific function. There must be a screen which acts both as a projection surface and as an adjuster of the rate of information processing. This screen may be related to the association areas of the brain with control of the reconstruction process being carried by the corticofugal fibers from these areas. Temporal encoding is a function of the orienting response.

Spinelli's Computer Model of Memory

A computer model of memory in the central nervous system has been described by Spinelli (1970). It is assumed that the basic structure of the memory system used by the brain is content-addressable, that is, information is stored in parallel. To retrieve a chunk of information, all that is necessary is to provide the system with a fraction of the chunk. Several hundred interneurons are assumed. Input cells and output cells are connected to a match cell and collaterals inhibit input cells in nearby networks. The interneurons are activated by the input activity in a sequential order. When a waveform is repeatedly fed into the computer, the program generates a waveform that, after about 50 trials, is almost identical to the original.

The Sokolov Model of the CNS as a Modeling System

Sokolov (1969a, 1969b) presented the thesis that the central nervous system is in itself a modeling system which builds models of the external world in which all parameters, including time, are represented. The complex processes by which this is accomplished are presented in a series of models. Four basic types of neurons are involved. These are concerned with extrapolation, comparison, efferent processes, and inhibitory processes with the neuroglia acting as an activating mechanism. Where a stimulus is administered repeatedly, a neural model of that stimulus is formed. If the incoming messages coincide with the expectancy generated by the extrapolating neurons, the orienting response terminates, altering the selection of information. If the stimulus is not exactly as expected, a mismatch between efferent and extrapolating neurons is signaled and the orienting response returns. This process of recognition can be modeled mathematically.

The Pfaff Model of Memory

Pfaff (1969) presented a neurological model of memory which postulated that neurons acting as units could store

information through modulations of the ordinary metabolic events that maintain electrical excitability. This type of memory model is parsimonious in that its assumptions are few and widely accepted. A stored memory item is represented by changes in the probabilities of firing in a set of neurons. In each neuron of the set, a lasting change of probability of firing would be caused by some metabolic change in that cell. The more a nerve cell is forced to fire at rates higher than its spontaneous rates of activity, the more ready it will become, metabolically, to respond to future excitatory input with long bursts of high-frequency firing. Conversely, the more a cell is prevented from firing at rates as high as its spontaneous rate, the more it will become susceptible, metabolically, to inhibition. The model relies on a great diversity of connection among plural stimulus and response representations.

CONCLUDING REMARKS

In the literature on reading, it is not uncommon to find unqualified statements that reading is a language process, a psychological process, a psycholinguistic process, a physiological process, etc. Even the brief reviews in this section should have sufficed to show that such statements are wrong insofar as they imply exclusiveness. Reading is all these things and more. To understand its complexities will require the efforts of scholars in a variety of disciplines. Not the least difficult task will be the development of approaches and terminologies that will allow these scholars to interact meaningfully.

The models presented have similarities and differences that are apparent even in the short treatments accorded them here. Most come from the field of psychology, broadly defined, and a preponderance reflect an information-processing point of view. In these short treatments, however, similarities and differences in what the models seek to explain may be cloaked by diagrams that differ visually more than the processes they describe and by the individualistic, and even exotic, names given to the processes. Being based on information processing, most of the models describe one or more manifestations of information flow: (a) the extraction and transformation of the information itself, (b) the identification of the processing systems and their operating characteristics, and (c) the neurological substrata. In terms of the overused computer analogy, the models are concerned with the data being processed, the programs and program characteristics, and the computing equipment. This trichotomy is somewhat artificial in that the models concerned with programming range widely, forming an essentially reductionist continuum connecting the models concerned with the data to those concerned with the equipment. Thus, while the psycholinguistic and neuropsychological models are

easily categorized at the extremes of the continuum, the models of memory vary from one extreme to the other.

Models differ widely in the rigor employed in their construction but these differences are not apparent in the intentionally uncritical reviews above. Some models are the product of a comprehensive knowledge of the research literature and intensive experimentation, while others are based on varying amounts of informal observation, intuitive logic, and introspection. Many models combine various levels of rigor in the components proposed and these differences are not always specified. For example, the model proposed by Sperling (1970) is based on extensive experimentation and closely reasoned logic in representing the direct information flow from input to output, but the details of the long-term memory systems seem based primarily on aesthetic symmetry with little hard evidence presented in their support.

The differences in rigor found within and between models are often a reflection of the state of knowledge about the phenomenon modeled. Models dealing with the broad aspects of reading tend to be less rigorous and less data-based. For example, models concerned with the broad-decision processes of language and memory show little agreement among themselves and less supporting evidence. On the other hand, those concerned with programming characteristics have large areas of agreement as compared with models of the same type of a few years ago. There can be little doubt that this convergence results from a rapidly expanding data base in an extremely vigorous field. Perhaps the most exciting developments, however, are in neurology and neuropsychology, where investigators have recently made significant breakthroughs in understanding sensory and information processing, particularly within systems related to vision. The important phenomenon may be a widening acceptance of the information-processing point of view at all these levels. Its importance lies in the possibility that it can provide a unified approach conducive to communication among specialists. Indeed, there is much evidence that this is happening.

One caution is necessary. It seems clear that the application to normal reading of most of the models presented is still some way off. Most of the models have been developed under highly controlled laboratory conditions, and care should be exercised in extending their implications beyond these conditions. A model constructed to explain how subjects respond to tachistoscopic exposures of artificially controlled luminance, duration, and contents can tell us much about the normal ongoing process of reading, but only after the differences between the two processes are understood. Similarly, extensive bridges are needed between the processes involved in memorizing unidimensional lists of trigrams and the complex memory processes of normal reading. It should be remembered,

however, that laboratory controls are designed to simplify the complexities of the normal situation. One fact heavily underlined by the models presented is, therefore, the very complex nature of the normal reading process. Given this complexity, the problems associated with reading instruction are not likely to be solved by simplistic now-oriented approaches. As E. B. Huey wrote in 1907: ". . . and reading itself, as a psycho-physiological process, is almost as good as a miracle. . . . Problem enough, this, for a life's work, to learn how we read!"

REFERENCES

Aderman, D., & Smith, E. E. Expectancy as a determinant of functional units in perceptual recognition. Cognitive Psychology, 1971, in press.

Bernbach, H. A. Replication processes in human memory and learning. In G. H. Bower & G. T. Spence (Eds.), The psychology of learning and motivation. Vol. 3. New York: Academic Press, 1969. Pp. 201-240.

Bernbach, H. A. A multiple-copy model for postperceptual memory. In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970. Pp. 103-116.

Biggs, J. B. Coding and cognitive behavior. British Journal of Psychology, 1969, 60, 287-305.

Broadbent, D. E. Perception and communication. New York: Pergamon Press, 1958.

Bryden, M. P. A model for the sequential organization of behavior. Canadian Journal of Psychology, 1967, 21, 32-56.

Chapman, C. A. An analysis of three theories of the relationships among reading-comprehension skills. Symposium on psycholinguistics and reading presented at the meeting of the International Reading Association, Kansas City, Missouri, May 1969.

Cohen, G. Some evidence for parallel comparisons in a letter recognition task. Quarterly Journal of Experimental Psychology, 1969, 21, 272-279.

Cohen, R. L., & Granström, K. Interpolated task and mode of recall as variables in STM for visual figures. Journal of Verbal Learning and Verbal Behavior, 1968, 1, 653-658.

Collins, A. M., & Quillian, M. R. Facilitating retrieval from semantic memory: The effect of repeating part of an inference. Acta Psychologica, 1970, 33, 304-314.

Conrad, R. Short-term memory processes in the deaf. British Journal of Psychology, 1970, 61, 179-195.

Crosby, R. M. N., & Liston, R. A. The waysiders: A new approach to reading and the dyslexic child. New York: Delacorte Press, 1968.

Crowder, R. G. The role of one's own voice in immediate memory. Cognitive Psychology, 1970, 1, 157-178.

Davis, F. B. Fundamental factors of comprehension in reading. Unpublished doctoral dissertation, Harvard University, 1941.

Davis, F. B. Research in comprehension in reading. Reading Research Quarterly, 1968, 4, 499-545.

Davis, F. B. Psychometric research on comprehension in reading. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 8-3 to 8-60.

Elkind, D. Development studies of figurative perception. In L. P. Lipsitt & H. W. Reese (Eds.), Advances in child development and behavior. New York: Academic Press, 1969. Pp. 2-26.

Feigenbaum, E. A. Information processing and memory. In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970. Pp. 451-468.

Gephart, W. J. Application of the convergence technique to basic studies of the reading process. Bloomington, Ind.: Phi Delta Kappa, 1970.

Geyer, J. J. Perceptual systems in reading: A temporal eye-voice span constant. Unpublished doctoral dissertation, University of California, Berkeley, 1966.

Geyer, J. J. Perceptual systems in reading: The prediction of a temporal eye-voice span constant. In H. K. Smith (Ed.), Perception and reading. Newark, Del.: International Reading Association, 1968. Pp. 44-53.

Geyer, J. J. Models of perceptual processes in reading. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 47-94.

Gibson, E. J. Perceptual learning and the theory of word perception. Paper presented at the meeting of the American Psychological Association, Miami Beach, Florida, 1970. (a)

Gibson, E. J. A working paper summarizing theory-based research on reading and its implications for instruction, Department of Psychology, Cornell University, 1970. (b)

Gibson, E. J., Gibson, J. J., Pick, A. D., & Osser, H. A developmental study of the discrimination of letter-like forms. Journal of Comparative and Physiological Psychology, 1962, 55, 897-905.

Gibson, E. J., Pick, A., Osser, H., & Hammond, M. The role of grapheme-phoneme correspondences in the perception of words. American Journal of Psychology, 1962, 75, 554-570.

Gibson, E. J., Osser, H., & Pick, A. D. A study of the development of grapheme-phoneme correspondences. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 142-146.

Gibson, E. J., Osser, H., Schiff, W., & Smith, J. An analysis of critical features of letters, tested by a confusion matrix. In H. Levin et al., A basic research program on reading. Ithaca, N. Y.: Cornell University, 1963.

Goodman, K. S. Reading: A psycholinguistic guessing game. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 259-272.

Hansen, D., & Rodgers, T. S. An exploration of psycholinguistic units in initial reading. Technical Report No. 74. Institute for Mathematical Studies in the Social Sciences, Stanford University, 1965.

Harcum, E. R. Parallel functions of serial learning and tachistoscopic pattern perception. Psychological Review, 1967, 74, 51-62.

Hochberg, J. Attention in perception and reading. In F. A. Young & D. B. Lindsley (Eds.), Early experience and visual information processing in perceptual and reading disorders. Washington, D.C.: National Academy of Sciences, 1970. Pp. 219-224. (a)

Hochberg, J. Attention, organization, and consciousness. In D. I. Mostofsky (Ed.), Attention: Contemporary theory and analysis. New York: Appleton-Century-Crofts, 1970. (b)

Hochberg, J. Components of literacy: Speculation and exploratory research. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. Pp. 74-89. (c)

Hochberg, J., & Brooks, V. Reading as intentional behavior. In H. Singer & R. B. Ruddell (Eds.), Theoretical models

and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 304-314.

Holmes, J. A. Factors underlying major reading disabilities at the college level. Unpublished doctoral dissertation, University of California, Berkeley, 1948.

Holmes, J. A. The substrata-factor theory of reading. In G. A. Figurel (Ed.), Reading and inquiry. Newark, Del.: International Reading Association, 1965. Pp. 317-319.

Holmes, J. A. The substrata-factor theory of reading: Some experimental evidence. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 187-197.

Hunt, E. What kind of computer is man? Cognitive Psychology, 1971, 2, 57-98.

Levin, H., Grossman, J., Kaplan, E., & Yang, R. Constraints and the eye-voice span in right- and left-embedded sentences. Language and Speech, 1971, in press.

Levin, H., & Kaplan, E. L. Eye-voice span (EVS) within active and passive sentences. Language and Speech, 1968, 11, 251-258.

Liberman, A. M., et al. Perception of the speech code. Psychological Review, 1967, 74, 431-461.

Llewellyn Thomas, E. Search behavior. Radiologic Clinics of North America, 196-, 7, 403-417.

Mackworth, J. F. Some models of the reading process: Learners and skilled readers. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 8-67 to 8-100.

Massa, R. J. The role of short-term visual memory in visual information processing. In W. Wathen-Dunn (Ed.), Models for the perception of speech and visual form. Cambridge, Mass.: M.I.T. Press, 1967. Pp. 171-179.

Meyer, D. E. On the representation and retrieval of stored semantic material. Cognitive Psychology, 1970, 1, 242-300.

Morton, J. Interaction of information in word recognition. Psychological Review, 1969, 76, 165-178.

Morton, J., & Broadbent, D. E. Passive versus active recognition models. In W. Wathen-Dunn (Ed.), Models for the

perception of speech and visual form. Cambridge, Mass.: M.I.T. Press, 1967. Pp. 103-110.

Neisser, U. Cognitive Psychology. New York: Appleton-Century-Crofts, 1967.

Norman, D. A., & Rumelhart, D. E. A system for perception and memory. In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970. Pp. 19-64.

Noton, D. A theory of visual pattern perception. IEEE Transactions on Science and Cybernetics, 1970, SSC-6, 349-357.

Pfaff, D. Parsimonious biological models of memory and reinforcement. Psychological Review, 1969, 76, 70-81.

Posner, M. I. Abstraction and the process of recognition. In G. H. Bower & J. T. Spence (Eds.), The psychology of learning and motivation: Advances in research and theory. New York: Academic Press, 1969. Pp. 44-100.

Posner, M. I., Boies, S. J., Eichelman, W. H., & Taylor, R. L. Retention of visual and name codes of single letters. Journal of Experimental Psychology Monograph, 1969, 79, 1-16.

Pribram, K. H. The amnestic syndromes: Disturbances in coding? In G. A. Talland & N. C. Waugh (Eds.), Pathology of memory. New York: Academic Press, 1969. Pp. 127-157. (a)

Pribram, K. H. The four R's of remembering. In K. H. Pribram (Ed.), On the biology of learning. New York: Harcourt, Brace, 1969. Pp. 191-225. (b)

Pribram, K. H. Looking to see: Some experiments on the brain mechanisms of attention in perception. In D. A. Hamburg, K. H. Pribram, & A. J. Stunkard (Eds.), Perception and its disorders. Baltimore, Md.: Williams & Wilkins, 1970. Pp. 150-162.

Reitman, J. S. Computer simulation of an information-processing model of short-term memory. In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970. Pp. 117-148.

Roberts, G. R., & Lunzer, E. A. Reading and learning to read. In E. A. Lunzer & G. F. Morris (Eds.), Development in human learning. New York: American Elsevier Publishing Co., 1968. Pp. 192-224.

Samuels, S. J. Factors which influence the word recognition process of skilled readers. In G. B. Schick & M. M. May (Eds.), Reading: Process and pedagogy. Milwaukee: National Reading Conference, 1970. Pp. 277-281.

Shiffrin, R. M., & Atkinson, R. C. Storage and retrieval process in long-term memory. Psychological Review, 1969, 76, 179-193.

Smith, D. E. P., & Carrigan, P. M. The nature of reading disability. New York: Harcourt, Brace, 1959.

Sokolov, A. N. Modeling properties of the nervous system. In M. Cole & I. Maltzman (Eds.), A handbook of contemporary Soviet psychology. New York: Basic Books, 1969. Pp. 671-704. (a)

Sokolov, A. N. Studies of the speech mechanism of thinking. In M. Cole & I. Maltzman (Eds.), A handbook of contemporary Soviet psychology. New York: Basic Books, 1969. Pp. 671-674. (b)

Sperling, G. The information available in brief visual presentations. Psychological Monographs, 1960, 74, 1-28.

Sperling, G. Successive approximations to a model of short-term memory. Acta Psychologica, 1967, 27, 285-292.

Sperling, G. Short-term memory, long-term memory, and scanning in the processing of visual information. In F. A. Young & D. B. Lindsley (Eds.), Early experience and visual information processing in perceptual and reading disorders. Washington, D.C.: National Academy of Sciences, 1970. Pp. 198-215.

Sperling, G., & Speelman, R. G. Acoustic similarity and auditory short-term memory experiments and a model. In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970. Pp. 151-202.

Spinelli, D. N. OCCAM: A computer model for a content-addressable memory in the central nervous system. In K. H. Pribram & D. E. Broadbent (Eds.), Biology of memory. New York: Academic Press, 1970. Pp. 193-306.

Triesman, A. M. Selective attention in man. British Medical Bulletin, 1964, 20, 12-16.

Venezky, R. L., & Calfee, R. C. The reading competency model. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 273-291.

Wanat, S. F. Linguistic structure in reading: Models from Project Literacy research. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 8-155 to 8-177.

Waugh, N. C. Primary and secondary memory in short-term retention. In K. H. Pribram & D. E. Broadbent (Eds.), Biology of memory. New York: Academic Press, 1970. Pp. 63-66.

Wheeler, D. D. Processes in word recognition. Cognitive Psychology, 1970, 1, 59-85.

Wickelgren, W. A. Context-sensitive coding, associative memory, and serial order in (speech) behavior. Psychological Review, 1969, 76, 1-15.

Wickelgren, W. A. Multitrace strength theory. In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970. Pp. 65-102.

Williams, J. P. A review of several theories and models of reading acquisition. In F. B. Davis (Ed.), The literature of research in reading, with emphasis on models. New Brunswick, N. J.: Graduate School of Education, Rutgers University, 1971. Pp. 7-141 to 7-165.

Wilson, H. A. An investigation of linguistic unit size in memory processes. Technical Report No. 102. Institute for Mathematical Studies in the Social Sciences, Stanford University, 1966.

SUPPLEMENTARY REFERENCES

Belmont, J. M., & Butterfield, E. C. The relations of short-term memory to development and intelligence. In L. P. Lipsett & H. W. Reese (Eds.), Advances in child development and behavior. Vol. 4. New York: Academic Press, 1969. Pp. 30-82.

Bennik, F. D., Schwarcz, R. M., & Silberman, H. F. Linguistic and tutorial modeling for natural language CAF. Paper presented at the annual meeting of the American Educational Research Association, Los Angeles, 1969.

Binder, A., & Wolin, B. R. Information models and their uses. Psychometrika, 1964, 29, 29-54.

Bishop, C. H. Transfer effects of word and letter training in reading. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 215-221.

Bower, G. H. Organizational factors in memory. Cognitive Psychology, 1970, 1, 18-46.

Bower, G. H., & Springston, F. Pauses as recoding points in letter series. Journal of Experimental Psychology, 1970, 83, 421-430.

Broadbent, D. E. Information processing in the nervous system. Science, 1965, 150, 457-462.

Calfee, R. C. Information-processing models and curriculum design. Educational Technology, 1970, 10, 30-38.

Cofer, C. N. Some evidence for coding processes derived from clustering in free recall. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 188-192.

Ellis, N. R. The stimulus trace and behavioral inadequacy. In N. R. Ellis (Ed.), Handbook of mental deficiency. New York: McGraw-Hill, 1963. Pp. 134-158.

Fishman, E. J., Keller, L., & Atkinson, R. C. Massed vs. distributed practice in computerized spelling drills. Technical Report No. 117. Institute for Mathematical Studies in the Social Sciences, Stanford University, 1967.

Gustafson, H. W. Model for the analysis of talkspurt and silence durations in conversational interactions. Paper presented to the annual meeting of the American Psychological Association, Washington, September 1969.

Hively, W. A framework for the analysis of elementary reading behavior. American Educational Research Journal, 1966, 3, 89-103.

Hockett, C. F. Analysis of English spelling. Cooperative Research Report No. 639, U.S. Office of Education, Washington, D.C., 1963.

Hunt, E. B. Simulation and analytic models of memory. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 49-59.

Jenkins, J. J. Meaningfulness and concepts: Concepts and meaningfulness. In H. J. Klausmeier & C. W. Harris (Eds.), Analyses of concept learning. New York: Academic Press, 1966. Pp. 65-79.

Kling, M. General open systems theory and the substrata-factor theory of reading. In A. J. Kingston (Ed.), Use of theoretical models in research. Newark, Del.: International Reading Association, 1965. Pp. 70-123.

Levin, H., & Kaplan, E. L. Grammatical structure and reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. Pp. 119-133.

Luria, A. R. Speech development and the formation of mental processes. In M. Cole & I. Maltzman (Eds.), A handbook of contemporary Soviet psychology. New York: Basic Books, 1969. Pp. 121-162.

Rabbitt, P. M. A. Three kinds of error signaling in a serial choice task. Quarterly Journal of Experimental Psychology, 1968, 20, 179-188.

Rodgers, T. Linguistic considerations in the design of the Stanford computer-based curriculum in initial reading. Technical Report No. 111. Institute for Mathematical Studies in the Social Sciences, Stanford University, 1967.

Samuels, S. J. Effect of word associations on the recognition of flashed words. Journal of Educational Psychology, 1969, 60, 97-102.

Samuels, S. J. Modes of word recognition. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 23-37. (a)

Samuels, S. J. Recognition of flashed words by children. Child Development, 1970, 41, 1089-1094. (b)

Samuels, S. J., & Chen, C. E. Comparison of word recognition strategies of adults and children. In F. Greene (Ed.), Twentieth Yearbook of the National Reading Conference. Milwaukee: The National Reading Conference, 1971, in press.

Smith, K. U., Cambria, R., & Steffan, J. Sensory-feedback analysis of reading. Journal of Applied Psychology, 1964, 48, 275-286.

Spitz, H. H. Field theory in mental deficiency. In N. R. Ellis (Ed.), Handbook of mental deficiency. New York: McGraw-Hill, 1963. Pp. 11-40.

Underwood, B. J. Attributes of memory. Psychological Review, 1969, 76, 559-573.

Zeaman, D., & House, B. J. The role of attention in retardate discrimination learning. In N. R. Ellis (Ed.), Handbook of mental deficiency. New York: McGraw-Hill, 1963. Pp. 159-223.

SECTION 6

PAPERS ON LANGUAGE DEVELOPMENT

AND READING

6-2/ 6-3

LANGUAGE MODELS AND READING*

Irene J. Athey

University of Rochester

INTRODUCTION

The efficacy of a model† depends on certain criteria. Of these, parsimony, coherence, correspondence with reality, and heuristic value are primary considerations. This review evaluates the status of the major models of language development with respect to the criteria above, and examines the validity of their basic assumptions, the explanatory power of their key concepts, and the testimony of pertinent research.

This literature search is based on the premise that a thorough understanding of all the perceptual, cognitive, linguistic, and affective aspects of reading is essential if we are to comprehend the complex processes occurring in the fluent reader or in the child who is learning to read. This review provides a survey of linguistic models in order to examine the relevance of language-acquisition processes for reading.

For convenience, the models have been categorized and discussed in groups. There is nothing inherently superior about the classification adopted. It was suggested by Hayes's (1970) statement that the major contributions to knowledge about language acquisition have come from three sources: developmental psychology, psycholinguistics, and information processing.

The final section summarizes the results of the analysis of language models and discusses possible implications for the psychology of reading.

---

*The author is indebted to Sandra Baer, Mary Culkin, Bonnie Mardis, and Alice Salzberg for their assistance in reviewing the literature.

†Gephart's (1970, p. 38) definition has been used as a guideline in identifying models: A model is a representation of a phenomenon which displays the identifiable structural elements of that phenomenon, the relationships among those elements, and the processes involved in the natural phenomenon. The term "models" includes both comprehensive and partial models.

MODELS OF LANGUAGE ACQUISITION

Developmental Models

Developmental models may be classified as behaviorist, nativistic, and cognitive.

Behaviorist Models

Some of the fundamental issues which have divided philosophy over the centuries are reflected in the dichotomic line that psychologists draw between behaviorist theories and organismic or cognitive field theories. Within the behaviorist school of thought, which follows the tradition of the empiricist philosophers, the classical conditioning tradition, created by Pavlov, and followed by many Russian psychologists and some American theorists such as Guthrie, is sharply contrasted with the operant conditioning tradition, headed by Thorndike and continued by Hull, Skinner, Mowrer, and others.

Pavlov. Classical conditioning theory presents the simplest paradigm of learning, in which a conditioned stimulus (bell) presented in close temporal proximity with an unconditioned stimulus (food) after a number of trials gives rise to the original response (now called a conditioned response or CR) when presented alone. Pavlov also introduces the concepts of excitation, imitation, inhibition, discrimination, and generalization which, together with the conditioning paradigm, explain all learning, including language learning. In a review of the work on speech and verbal learning, Elkonin (1957) quotes Pavlov's description of language as a "second signal system":

> If our sensations and ideas caused by the surrounding world are for us the first signals of reality, concrete signals, then speech, especially and primarily the kinesthetic stimulations which proceed from the speech organs to the cortex, constitute a second set of signals--the signals of signals. They represent an abstraction from reality and make possible the forming of generalizations which, in turn, constitute our extra, specifically human, higher thinking [pp. 47-48].

The "signals of signals" are not simply second-order CR's. All animals are capable of second-order conditioning, and this does not constitute a higher level of mental processes. The higher-level human system is not primarily a signal of another signal, but a signal of many and various signals; i.e., it is a second-order CR conditioned to a complex stimulus which forms a system. The characteristic nature of this system is not just links and analysis of stimuli, but a synthesis (abstractions or generalizations, or both). However, as Bogoiavlensky (1957) points out, the same fundamental

laws governing the first signal system are thought to govern the second signal system since they involve the same brain tissue.

Although the classical conditioning paradigm suggests a very low and passive level of learning, Russian psychologists are primarily interested in the higher mental processes, and view the human organism as extremely active, mobile, and self-regulating, all of which behavior is, however, accountable in terms of the basic concepts of Pavlovian theory.

Watson. Following the classical conditioning tradition, Watson (1913) proposed a "substitution theory," in which words evoke the same kind of responses as their referents; e.g., the word "apple" is the stimulus for incipient biting and chewing responses similar to those evoked by the real apple. Thinking, in terms of this hypothesis, becomes a sequence of covert responses in the musculature of the mouth, face, and body parts.

Skinner. The second tradition of behaviorism is operant conditioning, and the application of its principles to language has been discussed by Skinner (1957, 1966, 1969), Mowrer (1948), Dollard and Miller (1950), and Bandura and Walters (1963). The basic principle is contained in Skinner's "three-term contingency" model, S-R-S, in which the stimulus (sight of food) elicits the response (putting food in mouth), and the reinforcing stimulus (taste of food). Food is an example of a primary reinforcer, because it fulfills a biological need, but much of human behavior depends on secondary reinforcers, which have been associated with primary reinforcers in the past. Language learning is explained in terms of the reinforcement of imitative behavior. For example, babbling gives way to infant speech because sounds which approximate adult speech become reinforcing in their own right as a result of being reinforced while the parents are present (Jenkins & Palermo, 1964; Mowrer, 1948). As he grows older, the child's language behavior is "shaped"--he is rewarded for successive approximations to adult pronunciation and grammar. Later, his speech is rewarded when the hearer complies with his requests, or comments on his statements, answers his questions, and so forth. Speech utterances that make a demand on the hearer are called "mands" while those concerned with naming are called "tacts." Tacts receive more general reinforcement, while for mands the reinforcement tends to be specific behavior on the part of the listener. In a dialogue, reinforcement is reciprocal, and quite complex, but no new principles are required beyond those of operant conditioning. A person's verbal behavior is shaped by the reinforcement contingencies of the verbal community in which he lives. Reinforcement and imitation thus play a fundamental role in operant-conditioning theories of language. In his latest work, Skinner (1969)

has elaborated the "contingencies" of reinforcement, without special reference to language, however.

Carroll. Carroll (1959) presented "an operational model for language behavior" based on his "agreement with large parts of Skinner's analysis of behavior, including much (though not all) of his model of verbal behavior [p. 37]." The model resembled a computer program, and included routines for stimulating the acquisition of a mand or a tact, for coalescing mands and tacts, and for acquiring a sentence. The model is comprehensive for what it aims to cover, but it does not seriously consider transformational theory (see a subsequent section on Psycholinguistic Models).

Carroll (1959) concludes that

> . . . the operational model needed in the psychology of language is a relatively simple one. It can be reduced to a small number of statements about perception, reinforcement, discrimination, and performance. What contributes to the apparent complexity of the model is the fact that the basic principles are capable of generating higher-order systems of immense intricacy, including systems for generating still further higher-order systems [p. 45].

Later works of Carroll (1964a, 1964b, 1964c, 1966) indicate a change in emphasis. The earlier focus on a behavioristic model has given way to a more eclectic consideration of the contributions of behavioristic, developmental, and linguistic models of language acquisition.

Bandura. In his work on children's copying behaior, Bandura (1965) draws a distinction between learning of new behaviors, which is accomplished through imitation and entirely without reinforcement, and performance which is dependent on reinforcement; operant-conditioning methods are considered effective in strengthening and maintaining responses that already exist, but they are not sufficient for developing new behaviors. Bandura was able to produce immediate behaviors in children that were very similar to those of the models. Bandura and Menlove (1968) found, furthermore, that rewarding the model increased the imitative behavior of the children, but if the model was punished, children learned the behavior (could describe it in detail) but did not perform it. In their experiments in extinguishing the fear of dogs in children, Bandura and Menlove found that presenting a diversity of models and aversive stimulus objects (animals) increased the effectiveness of their methods.

Probabilistic models. To explain the acquisition of grammar, behaviorists have traditionally adopted a probabilistic model ("Markov process"), in which each word in a sentence

is determined by those immediately preceding it. Each word in the sentence becomes the stimulus for the next word in accordance with the associative laws (e.g., frequency, contiguity, etc.) of the particular version of behaviorism the theorist espouses. Probabilistic models rely heavily on the concept of stimulus and response generalization whereby a range of stimuli may evoke the same response, or a range of responses may be attached to the same stimulus. The concept of generalization is basic to all behaviorist theories, but may occur in somewhat different form.

Braine. Braine (1963), for example, posits a "contextual-generalization" hypothesis emerging from his distinction between pivot and open classes. Pivot words (my, more, allgone, etc.) are relatively few in number, emerge slowly, and have a fixed position in the child's sentences. The open class contains many nouns, adjectives, etc., which fill the remaining slots in two- and three-word utterances, resulting in such phrases as "my big truck," allgone milk," etc. Contextual generalization is the process whereby the child, having established the meaning of a pivot word, is able to expand his repertory of intelligible utterances considerably. It is not essentially different from stimulus or response generalization except that it takes place across temporal positions. For example, upon hearing "Will you/go to the store?" the child observes that "you" occurs in the first half of the sentence and "go" in the second half. "You" and "go" are then carried into new analogous contexts by the process of contextual generalization, enabling the child to construct longer and longer sentences. This process explains his linguistic productivity.

Jenkins and Palermo. Jenkins and Palermo (1964) have proposed a theory to explain the learning of grammar, which they view as a basic problem in language acquisition. By repeatedly hearing sentences of the same form (e.g., subject-verb-object), the child learns the abstract sequence, enabling him to generate new sentences. Although the explanation is not carried beyond this level, presumably more complicated grammatical structures are acquired through the same process of generalization. More recently, Jenkins (1968) has modified this view, in recognition of the linguists' distinction between deep and surface structure. Psychologists frequently confine their investigations to the surface structure; hence their findings are necessarily restricted to this aspect of language. Jenkins believes that further study of the deep structures of behavior will lead to an improved understanding of the relevant aspects of the surface structures.

Staats and Staats. Staats and Staats (1962, 1963) and Staats (1968) have developed a complex account of language behavior in the Skinnerian tradition using, in addition to reinforcement, imitation, successive approximation, generalization and discrimination, and the concept of mediation. A

word is said to have meaning when part of the covert response to the object is transferred to the word by conditioning. This implicit response is a mediating response. Mediating responses are names, labels, or linguistic responses which mediate between stimuli and behavior (Jensen, 1966). Mediation is derived from simple S-R associations in which one stimulus elicits several responses, or several stimuli elicit the same response, or a response in one situation is a stimulus in another situation. Mediation is thus held to account for much complex linguistic and cognitive behavior (Staats, 1968).

Mowrer. Mowrer (1948, 1954), too, relies heavily on the concept of mediation. Words are combined in sentences to produce new meanings (mediating responses), which cannot be produced by the individual words alone. Some of the responses to individual words are transferred to other words by virtue of their pairing in sentences. In this way, a person learns new associations through language, without experiencing objects and events directly.

Osgood. Osgood's (1969) theory of how words acquire their meaning is similar to Mowrer's. Words become signs for things because they produce some fraction of the actual behavior toward these things. This is accomplished through a representational mediation process in which the signs (words) are associated with the stimulus objects. Later, when the signs occur without the presence of the objects, "they tend to elicit some reduced portion of the total behavior elicited by the stimulus object [p. 9]." Those responses which require the most energy are the least likely to survive the reduction process. Therefore, although these responses may be overt, they are more likely to be covert, and are probably cortical in most instances. Osgood distinguishes between representational mediation theory, as represented by Mowrer and himself, and nonrepresentational theory, represented by Skinner, Bousfield, Jenkins, and in a more complex fashion, Braine. In nonrepresentational mediation theory, the mediating response to the sign is a replica of the response to the stimulus object, while representational mediation theory holds that this response is a "nonobservable, proper part (but not replica)" of the total response to the stimulus object (Osgood, 1968).

Representational mediation can be divided into two processes, decoding and encoding. Decoding involves the association of signs with their mediating responses, or meaning. These reactions automatically produce internal stimulation. Decoding corresponds to the transition from surface to deep structure which appears in the linguists' accounts of language. Encoding is the reverse process in which the internal stimulation produced by the mediating responses evokes overt acts, such as speaking, gesturing, or obeying commands. Since

these two processes can occur independently of each other, a child usually learns the meaning of words before he learns to speak them (Osgood, 1957). Osgood further suggests that semantic and syntactic features of language are not basically different, but fall on a continuum.

Osgood, Suci, and Tannenbaum (1969) see the mediating response as being compound rather than simple. They have developed a method for measuring this response, called the semantic-differential technique. Subjects rate words in terms of a pair of polar terms, such as hot-cold. These judgments are then correlated and used in various ways. It is assumed that these pairs of polar terms correspond to the components of the mediating response. The particular pair of terms indicates which response is being measured, while the extremeness of the judgment reflects the intensity of the response. Each component response is seen as a pair of "reciprocally antagonistic" reactions (like the polar terms).

This brief exposition of behaviorist models of language acquisition demonstrates how, by using basic stimulus-response terminology, various theorists have endeavored to explain the acquisition of vocabulary, grammar, and meaning.

Research Literature on Behaviorist Models

Behavioristic theory has been generally successful in stimulating research to validate or clarify the key concepts of reinforcement, generalization, discrimination, extinction, imitation, and mediation in many areas of inquiry, including language.

The classical conditioning version of language acquisition has produced several confirming studies. Two Russian studies (Bassin & Bein, 1961; Novikova, 1961) measured the electric charges in the mouth and facial muscles, while subjects were engaged in problem-solving tasks, and found that these charges increased as the tasks became more difficult. However, Osgood (1952) reviewed the work of the twenties and thirties and concluded that the substitution theory is inconsistent with the facts; responses to the word "apple" are not the same as to a real apple. Moreover, the responses to abstract words such as "happiness" could not be of this kind.

Reinforcement. Operant conditioning techniques have been used to teach language in a variety of situations. Bereiter and Engelmann (1966) and Osborn (1968) have taught pronunciation and syntax to disadvantaged preschoolers. Hart and Risley (1968) used snacks, teacher approval, and access to play equipment as reinforcers to increase disadvantaged preschoolers' use of descriptive adjectives in spontaneous speech. Gray and Fygentakis (1968) employed the same

principles to teach "linguistically divergent" children, but by varying the stimulus situation they also worked for response generalization from the "is" paradigm, which was taught, to the "is--ing" paradigm, which was not. Sapon's (1966) attempts to teach speech to Mongoloid children according to operant-conditioning principles have been successful, although the children's speech after treatment is still far from normal. Similarly, Weiss and Born (1967) found that speech paradigms could be taught to a nonspeaking seven-year-boy as long as the original paradigms were followed.

Mediation. There is also available a wealth of literature on human mediation, primarily in the United States, which was reviewed by Spiker (1963), and in the Soviet Union, which was reviewed by Slobin (1966c). It has been suggested that very young children do not make mediating responses, the "mediation-deficiency hypothesis" (Reese, 1962), but that in older children such responses become unconscious and automatic (Jensen, 1966) as well as highly facilitating in problem-solving tasks, since they enable the subject to hold the solution in memory (Boat & Clifton, 1968; Potts, 1968). Of course, the mediating response may occasionally produce an incorrect solution, as when perceptual memory is distorted by the application of a label (Carmichael, Hogan, & Walter, 1932), but this confirms rather than weakens the concept of mediation.

Hence, there is considerable experimental evidence to support the contention that the basic concepts of behaviorism correspond to psychological processes occurring within the organism.

Critique of Behaviorist Models

The major strength of behaviorist theories lies in their parsimony and objectivity. Mentalistic concepts that are difficult to verify experimentally are exorcised, while those retained in the system are operationally defined in behavioral terms. There is a parsimony and coherence of relationships among the basic concepts, giving the entire theoretical system an air of elegance and scientific rigor. Moreover, it is held to be comprehensive in that its principles have explanatory power for all aspects of human and animal behavior.

Critics of behaviorist theories maintain that this appearance of objectivity and rigor is illusory, and that parsimony of concepts is obtained at the expense of explanatory value. Chomsky (1959), who led the attack in his critical review of Skinner's Verbal Behavior (1957), has pointed out that the terms stimulus, response, reinforcement, extinction, generalization, and discrimination are used in imprecise ways.

In summary, Chomsky's criticisms were: (a) the goal of the book is to provide a way to predict and control verbal behavior by observing and manipulating the physical environment, which is manifestly impossible. The only hope of predicting the behavior of a complex organism is through an indirect program of research that begins by studying the behavior and the particular capacities of the organism; (b) Skinner takes experimental results and, by making analogic guesses, creates the illusion of a theory having scientific rigor and broad scope, whereas in fact, the descriptions of real life and of behavior in the laboratory are only vaguely similar; and (c) the concepts of stimulus, response, reinforcement, drive reduction, and probability of response are vague cover terms which are entirely inappropriate to describe verbal behavior. As McNeill (1970) points out: "It is the phenomenon of abstraction, which all children face and overcome, that eliminates stimulus-response theory as a possible explanation of language acquisition [p. 1086]."

Recently, MacCorquodale (1969, 1970) has attempted to counteract the negative reactions to Skinner's book which have been brought about by the "uncritical acceptance of [Chomsky's] misconceptions concerning _Verbal Behavior's_ content [1969, p. 831]." It is "best conceived as a _hypothesis_ that speech is within the domain of behaviors which can be accounted for by existing functional laws, based upon the assumption that it is orderly, lawful, and determined. . . ." Like all hypotheses, "this one asserts more than the author has yet demonstrated experimentally, and it sounds dogmatic. We expect and tolerate this in hypotheses [p. 832]." Skinner probably avoided the word "hypothesis," because it suggests some fictional element, but a strong argument for his theory is that "it contains no reference to fictional causal entities [1970, p. 85]." In fact, it is Chomsky who is being unparsimonious in supposing that nature maintains two sets of laws: one for the laboratory, another for real life.

All in all, MacCorquodale finds Chomsky's criticisms "irrelevant" (indeed many of them are more applicable to non-Skinnerian theory), and concludes that "we do not yet know if verbal behavior is within the domain of Skinner's system."

As indicated earlier, Carroll (1964a, p. 38) has also expressed some dissatisfaction with the Skinnerian model. He summarizes the major difficulties as follows:

1. The theory on the whole relies heavily on the concept of reinforcement, but not everyone is willing to accept the proposition that reinforcement is the crucial factor in learning.
2. The theory cannot account for the fact that a language response learned in one way is immediately available for use in other ways.

3. If we look more closely at the paradigms postulated by Skinner, we notice that in all cases there must be covert perceptual responses to the rewards (in case of mands) or to the discriminative stimuli (in the case of tacts). In the process of operant conditioning, then, classical conditioning, or something very much like it, must be going on in parallel.

Imitation. Several key concepts of operant theory have come under attack, notably imitation and generalization. With respect to imitation it may be noted that: (a) children's ability to reproduce sentences they hear is limited to what they can produce in spontaneous speech (Ervin, 1964); (b) the order in which inflections appear in children's speech is weakly correlated with the frequency of these forms in the speech of the adults they hear (Bellugi, 1964); (c) when children fail to comprehend a sentence they are asked to imitate, the imitation either expresses a different meaning or no meaning at all (Slobin & Welsh, 1967); (d) since children reconstruct adult models to make their own grammars, imitation plays no role in the acquisition of new transformations (McNeill, 1970); (e) children often produce regular forms of irregular verbs (e.g., digged) even though they have never heard these forms in adult speech (Ervin, 1964); (f) children omit certain aspects of the model's utterance, e.g., his gruffness of voice; and (g) a child can pick up a second language from other children who are not precise or accurate in their speech (Chomsky, 1959).

McNeill (1970) makes a distinction between two uses of the term imitation. The first is a general use, as for example, writing prose in the style of Faulkner, or driving on the right-hand side of the road. In this broad sense, children acquire language through imitation. The second is a narrower, more technical use, which involves copying the behavior of a model, e.g., making plural inflection on English nouns. It is this technical use, he maintains, that is inappropriate for language acquisition.

Generalization. The concept of generalization has also been the object of some criticism. One difficulty appears to be that children classify words into the pivot or open class in ways consistent with more subtle differentiations that they will make in the future. McNeill (1966a), for example, cites the case of a child whose pivot class contained members of several adult grammatical classes (demonstratives, adjectives, possessives, etc.) although none of these classes were at that time a part of the child's grammar (McNeill, 1970).

Braine's contextual generalization has given rise to considerable dispute. While it is true that positional learning, extended through contextual generalization, can lead to

grammatically correct complex sentences, a difficulty arises when the surface structure of sentences is not necessarily the same as the underlying structure (Bever, Fodor, & Weksel, 1965). Braine's (1965) solution of changing the syntactic analysis of sentences by construing them all as having the same surface and underlying structures is viewed by McNeill (1968a) as avoiding the problem of language acquisition altogether. The theory also fails to explain the child's restriction on the use of pivot words (McNeill, 1970). Slobin (1971a) refers to two cross-cultural studies (Blount, 1969; Kernan, 1969), which argue for the insufficiency of pivot analysis, and points out that for some children a distinct pivot stage may not occur.

Probabilistic models. Probabilistic models have come under repeated attack from psychologists as well as linguists. Lashley (1951) pointed out that there is no intrinsic order to words which could account for either production or comprehension of speech through association. He concludes that there must be an underlying level at which longer units than those momentarily being produced are being formulated. Moreover, there is a clearer intrinsic relationship between certain parts of a sentence than others; in a sentence such as "the boy hit the ball," "the ball" is a unit, whereas "hit the" is not. Chomsky (1957) further demonstrated that the model is incapable of differentiating between sentences which are grammatical and those which are not. The sentence "Colorless green ideas sleep furiously" is grammatical, but the probability of its occurrence (except in books on psycholinguistics) is virtually nonexistent. The model is equally incapable of accounting for the different structures underlying the two meanings of an ambiguous sentence ("They are cooking apples") and for the insertion of phrases between stimulus and response words which occurs in embedded sentences ("The man I met last week is here"). In brief, it appears that "our knowledge of language involves properties of a much more abstract nature, not indicated directly in the surface structure [Chomsky, 1968, p. 32]."

Mediation. Fodor (1965) has objected to the analysis of meaning in terms of mediational responses, pointing out that not all words refer directly to things, and that even those which do may have several referents; words refer to categories, not things (Brown, 1958). The mediating responses often seem to be images (Mowrer, 1960; Staats & Staats, 1963), but image theories of meaning present many problems (Brown, 1958).

Basically, the linguists' position is that behaviorist models are simply incapable of accounting for the known facts of language development. Behaviorists in turn dismiss this contention, maintaining that "integrated learning theory is fully capable of indicating in a credible and useful manner

how language behaviors mediate such cognitive behaviors as reasoning, problem solving, intelligence, perception, and so on [Staats, 1968, p. 158]." Likewise, MacCorquodale (1969, 1970) has dismissed Chomsky's review as irrelevant to Skinner's account of verbal behavior. In spite of these disclaimers, no satisfactory response to the powerful arguments enumerated above is as yet forthcoming.

Nativistic Models

Lenneberg. Lenneberg (1967) presents a theory based on the premise that language has a biological basis and is the manifestation of species-specific cognitive propensities. "A biological predisposition for the development of language is anchored in the operative characteristics of the human brain." Thus, language is a peculiarly human function to which animal communication shows no evidence of approximation. Recent work by Thorpe (1967), Hockett and Altman (1968), Gardner and Gardner (1969), and Premack (1970) which argues for a continuity hypothesis might present a challenge to Lenneberg's position and the evidence at this point appears inconclusive.

As evidence of the biological, species-specific nature of language, Lenneberg presents a vast array of evidence from genetic, neurological, and psychological sources. First, language appears to be closely tied to general maturation. Important milestones in language acquisition are reached in a fixed sequence which cannot be accelerated by special training and are largely unaffected by such variables as intelligence, parental attitudes, or effectiveness in communication. Maturation of the latent language structures brings about a state of readiness, at which time adult speech elicits a "resonance" which releases the synthesizing process by which the child builds his own language structure. Hence there is a critical period for language acquisition (two to four years) corresponding to certain aspects of brain development. At adolescence there occurs "the phenomenon of cerebral lateralization of function" at about the same time that the capacity for primary language acquisition declines. Cross-cultural research studies reveal the same sequence of linguistic events. Lenneberg, it should be noted, is opposed to the doctrine of localization of brain functions.

As further evidence of the innate biological basis of language, Lenneberg points to the universal properties of language: (a) all languages have a phonemic system; (b) all are concerned with the same aspects of the environment; (c) all languages can be judged as either grammatically acceptable or unacceptable; and (d) the syntax of languages is basically of the same type, consisting of words or morphemes that fit into functional categories. Language universals are determined by the limitations set by the cognitive functions characteristic

of man. Concept formation is primary; applying linguistic terms to the categories is a secondary process. Maturation of cognitive processes comes about through progressive differentiation of experience, a traversing of highly unstable states whose disequilibrium leads to rearrangement of the elements of thought, adult thought being characterized by relatively stable arrangements. The period of disequilibrium of language is of limited duration, however; it begins around two years of age and declines with cerebral maturation in the early teens.

Werner and Kaplan. Werner (1967) postulates a developmental principle which parallels Lenneberg's theory of cognitive development. It is

> an orthogenetic principle which states that wherever development occurs it proceeds from a state of relative globality and lack of differentiation, articulation, and hierarchic integration. . . . Perception is first global, whole qualities are dominant; the next stage might be called analytical (directed toward the parts). The final stage might be called synthetic (integration with respect to the whole) [pp. 126-128].

Like Lenneberg, Werner and Kaplan (1963, p. 9) view language as having a biological basis: "The environment is converted by both species-specific and individually learned patterns into a field of signals." They describe three stages in language development: (a) naturalistic-onomatopoetic depiction, in which meanings are represented primarily by sounds; (b) physiognomic depiction, in which meanings are conveyed by the pitch or tonal quality of sounds; and (c) transition to conventional language, in which symbols come to represent (not substitute for) their referents.

McNeill's model may also be considered nativistic, but in this review it appears in the section on psycholinguistic models, where a further discussion of linguistic universals may be found.

Research on Nativistic Models

As previously noted, Lenneberg's theory is founded on a wealth of evidence from diverse sources, including observational studies of orphanage children, field research in central Brazil, New Guinea, and the American southwest, and a large number of clinical studies of (a) aphasia due to brain trauma, and (b) of deaf children, etc.

It is also apparent that linguistic development follows the same sequence of stages regardless of the language to which the child is exposed. For example, McNeill (1966)

found that both English and Japanese children master a generative transformational grammar according tc certain universal principles. Ervin-Tripp and Slobin (1966) reported that the earliest grammar both in Russian and English appears before 2 years of age. In a further review, Slobin (1964) cited cross-cultural research on early stages of the acquisition of grammar as indicative of the universality of the stages and the process. Cazden (1969) has noted that studies of early language acquisition dc in fact show striking similarities in the stages of development across children, with equally striking deviations from adult grammar. Ervin and Miller (1963) observed that children acquire prelinguistic articulatory control by the age of 8-10 months, the onset of one- and two-word utterances between the ages of 1 to 2 years, and the use of plurals before age 3. Braine (1963) reported that 5 or 6 months after one-word utterances are established, children show an upsurge of different word combinations used in two-word utterances. (The number of different combinations recorded from one of Braine's children in successive months was: 14, 24, 54, 89, 350, 1400, 2500+ [McNeill, 1970].) Bellugi (1965) found a sequence of three stages between 18 and 36 months in the development of the interrogative. Ervin-Tripp (1970) also noted a fixed sequence in which responses to various types of questions were learned between the ages of 2.6 and 4.2 years. She further reports use of the past tense and the notion of intention as appearing between the ages of 3 and 4 years. McCarthy (1954, p. 526) observed the use of phrases and compound sentences after 2 years, and the use of clauses by 4-1/2 years. Anderson and Beh (1968) concluded that lexical markers are learned hierarchically during the first and second grades of school. A recent study by Eimas, Siqueland, Jusczyk, and Vigoritc (1971) showed that 1- and 4-month-old infants can discriminate consonant sounds in much the same way as adults. The peak of discriminability was found at the boundary between voiced and voiceless stops. Carlson and Anisfeld (1969) concluded from a longitudinal study of the development of a child's speech from the ages of 21 to 33 months that the child had an internal linguistic system and had acquired the patterns and sound relations inherent in English before he had mastered the specific sounds.

To show that language milestones are reached independent of environmental factors, Lenneberg (1967) points out that up to the age of 6 months, deaf babies and hearing babies born to deaf parents go through the same sequence of vocalizations as hearing children. Ervin and Miller (1963) also report that deaf children during the prelingual period (0-3 months) make the same sounds as hearing children. Lenneberg (1962) reported a case history of a child who was never able to speak, but who was at age 8 capable of understanding complex syntactic structures.

Mothers' attitudes toward their children are not predictive, according to Lenneberg (1967), of the emergence of various stages in speech development. Children in orphanages are often below average in speech development at 3, but have caught up by the age of 6 or 7, when the environment is enriched, providing the resonance necessary to trigger the child's latent language structure is present. Brown, Cazden, and Bellugi (1968), in their observations of parental utterances, found no evidence of the effect of reinforcement or communication effectiveness of parents on the appearance of milestones in language development.

To show that language is also relatively independent of intelligence, Lenneberg (1964b) draws on his studies of retarded children. Children with IQ's ranging around 50 all possessed language, though articulation and grammar were poor, and continued to develop until the early teens, when language development "freezes." Lenneberg, Nichols, and Rosenberger (1964) studied 54 Mongoloids ranging in age from 6 months to 22 years over a 3-year period, and found that 75 percent reached at least the first stage of language development, although no subjects over 14 made any progress at all.

The evidence above may be summarized by the statement that language development is a function of the growth of the human brain. Hence, the maturation of language parallels the maturation of motor skills and cognitive processes in general. Other authors have described the acquisition of language structures in terms reminiscent of accounts of concept formation. Glanzer (1962), for example, describes the development of grammar as a tentative theory which the child must validate by testing. Brown and Fraser (1964) concluded that the child constructs his grammar by imitating adult speech in reduced form and inducing general rules, and they discuss the evidence of induced rules presented by the overgeneralizations children make which lead to errors (see also Cazden, 1968). Rearrangement of this stable generalization produces further differentiation.

Werner and Kaplan document their theory with a wealth of examples, but little research has been conducted which tests their hypothesis. A few studies have been made to determine whether there is, in fact, a natural phonetic symbolism. It has been found, for example, that speakers of one language are able to recognize words in unfamiliar and historically unrelated languages. Slobin (1968) cites the fact that American subjects tend to agree in matching American and foreign polar opposites as support for the notion that sounds can have symbolic value. His subjects were required to identify groups of autonyms translated into Thai, Kanarese, and Yoruba. Brown, Black, and Horowitz (1955) asked native American speakers to match English words with translations into Chinese, Czech, and Hindu. They concluded, after three

separate investigations, that there was a consistency superior to chance agreement and accuracy in the translation of unfamiliar tongues. Miron (1961) used nonsense items, adhering to phonetic distribution laws of Japanese and English. He had native speakers judge these items on three composite scales: evaluative (good or bad); potency (large or small); and activity (quiet or noisy). He concluded that the materials had expressive symbolic value accruing to their inherent phonetic content. These and other investigations tend to support the concept of the universality of phonetic symbolism.

Critique of Nativistic Models

The publication of Lenneberg's book Biological Foundations of Language has been hailed as "the event of recent years" in this area (Fillenbaum, 1971). Carroll (1968) evaluates it as "an extraordinarily careful review and interpretive discussion of what is known of the biological substrate of language." Bem and Bem (1968, p. 499) find that "in sum, Lenneberg's presentation is persuasive, and the weaker spots . . . do not impair the thrust of his major thesis."

Maturation. According to Carroll (1968), Lenneberg has added new evidence to that of Gesell, McCarthy, and others to show that language development is maturationally dependent. However, he questions the corollary of this position, that there is a critical period for language learning.

> The notion of a biologically determined lower age limit for first language acquisition would, I think, be accepted by all but the most extreme behaviorist. The evidence for a *biologically* determined upper age limit . . . is not so clear. It rests primarily on observations of the poor prognosis for language learning in the unharmed hemisphere in aphasics beyond puberty. A counter-theory would be that the apparent loss of cerebral flexibility is due solely to the accumulation of well-formed habits that interfere with efforts to establish new habits of foreign pronunciation . . . or to learn any new skill [p. 118].

Biological basis of language. The evidence for the existence of linguistic universals is overwhelming but, Carroll warns, we must exercise caution in inferring that these are biologically dependent. There are universal features of other human systems which may depend more on logic or on "the nature of things" than on biologically given capacities. As one universal feature, Lenneberg cites the fact that "all languages are concerned with essentially similar aspects of the environment," a tacit admission, in Carroll's view, that "some universal characteristics of language may arise from

characteristics of the human environment rather than the human organism [p. 118]." Bem and Bem (1968) point out that

> it is not biological considerations which are prompting an increasing number of psychologists to accept some of the extraordinary conclusions about the innate character of linguistic competence, but the apparent failure of any current notions about learning to account for the new linguistic observations in even a remotely satisfying way [p. 498].

In other words, one may be persuaded of the innateness of certain linguistic competencies without necessarily being committed to the biological hypothesis.

Localization of speech functions. Whitaker (1969) is committed to the biological hypothesis. He praises Lenneberg for demonstrating the relevance of biology for the study of language. However, he is critical of his conclusions concerning the localization of brain function in language. Lenneberg maintains that clinical evidence based on studies of lesions of the brain is suspect because of the great variety of lesion types which are difficult to locate and isolate. Whitaker (1970) believes that his summary of research on the correlation between functions and brain loci makes a "plausible case" in support of the localization position. For example, Lenneberg argues that it is not possible to assign a specific neuroanatomic structure to language capacity. Whitaker agrees, but points to certain histological differences in the cortex of the speech areas. The anterior border of Brodmann's area 44 in man is unlike that of any other primate. Penfield and Roberts' (1959) and von Bonin's (1949) work also support Whitaker's position.

Cognition and language. Lenneberg argues that linguistic competence is part of a more general cognitive competence, but the nature of this relationship is not made clear, nor is the supporting evidence entirely persuasive. However, a review of other models reveals that the linguists are in no better position in this regard.

Learning. While Lenneberg must be credited with assigning a role to learning in his account of language development (as opposed to McNeill, for example), again the nature of the learning is not made explicit. Granted that language emerges "by an interaction of maturation and self-programmed learning [p. 158]," it becomes necessary to specify the principles by which the learning and the interaction proceed.

Resonance. It must also be admitted that the concept of resonance does not receive a satisfactory explanation in the discussion of language acquisition, nor is there a readily discernible method for verifying such a concept.

Fodor (1964) has written a highly critical review of Werner and Kaplan. He finds the book disappointing in that the authors, although they are discussing language, have completely ignored the investigations by linguists, psycholinguists, and philosophers. According to the authors, early language consists of onomatopoetic words resembling their referents which develop to the point where they become conventional or dissimilar. Fodor maintains that this position reflects associationist views, to which the authors are explicitly hostile.

In summary, we may say that nativistic models, especially Lenneberg's, have made a profound impact on the study of language. It is as yet too early to assess the validity of these models on the basis of research evidence. In addition, Lenneberg's theory has generated controversy concerning the nature of linguistic universals, the localization of brain function, and the continuity of human and animal speech. All these issues remain open, suggesting the need for further research before a valid assessment of the models can be achieved.

Cognitive Models

A consideration of language-acquisition models soon leads to the problem of the relationship between cognition and language. McNeill (1970) believes that, unlike S-R theories, theories of cognitive development may be quite appropriate to the task of explaining language. The problem, as he sees it, is an empirical one. It consists of determining whether the known facts of linguistic development can be understood in terms of the theory. This enterprise, which he calls the problem of "cognition and language," must be distinguished from the opposite question of language influencing cognition, which historically has been called the problem of "language and cognition."

McNeill goes on to say that the problem of cognition and language has not been widely recognized, since the most comprehensive theories of cognitive development (Piaget, Bruner, Vygotsky) take the general form of language for granted. They have either concentrated on the problem of language and cognition, or the expression of thought in language--which again is a different problem. Moreover, McNeill expresses some doubt as to whether existing cognitive theories could be manipulated or extended to account for the known facts of linguistic development. Certainly it is difficult to take a global theory and make it fit a specific body of factual knowledge, though in principle it should be possible if the theory is as comprehensive as it claims to be.

Piaget. Piaget's (1970a) theory is interdisciplinary and "involves, in addition to psychological elements,

components belonging to biology, sociology, linguistics, logic, and epistemology." It begins by postulating a biologically based human need for activity and learning. The tendency toward equilibration is an internal regulatory force which is manifested in all life, but particularly in the development and activity of intelligence (Furth, 1969). The child's activity brings him into situations which set up a tension. Through the complementary processes of assimilation and accommodation, the tension is resolved, and the child moves to a new level of equilibrium. However, the developmental status of the child determines the kind of stimuli which will evoke a state of tension at any given time. During the sensorimotor period, for example, the child is learning about the environment by interacting with people and objects. His primary task is to discover permanence and regularity in the objective phenomena around him. Toward the end of this period, he can hold these objects in memory by means of images and labels.

With regard to the relationship of his theory to linguistics, Piaget (1970a) states that

> the contemporary work of Chomsky and his group on transformational grammars is not very far from our own operational perspectives and psychogenetic constructivism. But Chomsky believes in the hereditary basis of his linguistic structures, whereas it will probably be possible to show that the necessary and sufficient conditions for the construction of the basic units on which are founded the linguistic structures are satisfied by the development of sensorimotor schemes [p. 729].

The period of language acquisition falls almost entirely in the later sensorimotor and the preoperational stages of intellectual development, when the sounds of language come to have particular salience for the child. During this period (two to six years) the semiotic function begins to operate. "[It] detaches thought from action and is the source of representation. Language plays an important part in this formative process [Piaget & Inhelder, 1969, p. 85]." The sensorimotor child's thought structures are limited to the here and now, and must progress step by step. By contrast the preoperational child can represent all the elements of an organized thought simultaneously, can use a variety of symbols, and can range over space and time in his thinking. Use of symbols does not imply that the child knows the structures underlying the concept expressed. Piaget and others have conducted a large number of studies showing the gradual metamorphosis in the content of such concepts as space, time, right, left, brother, democracy, justice, etc. On the other hand, Piaget's theory implies that the prelingual child acquires a wealth of understanding about the continuity and regularity of the physical and social world without benefit

of language. Language is structured by logic, rather than the reverse. It is a highly sophisticated tool to be used in understanding the environment, but it cannot in itself bring about that understanding unless the symbol system is grounded in concrete experience.

Piaget draws a distinction between egocentric speech (which characterizes the first years of language usage, and is largely an expression of the child's needs, impulses, and emotions) and sociocentric speech (which serves the purpose of relaying information). Egocentrism is an all-pervasive characteristic of the young child's thought; it represents an inability to view physical or mental phenomena from a perspective other than the one the child is currently taking. Speech is egocentric in the sense that it is not adapted to the listener. Manifestations of egocentric speech are found in monologues (individual and collective), repetitions, gestures, mimicry, and movements. Piaget's well-known example is the child's retelling of a story to a naive listener. The narrator omits significant detail and uses pronouns which are ambiguous in reference, etc. The result is a garbled and incomprehensible version of the original. It is also noticeable that, in making reference to themselves, children rarely use the personal pronoun, as though the implied subject were automatically understood by the listener.

In the preoperational stage, egocentric speech constitutes almost half of the child's utterances, but gradually it falls out of his language system and is replaced by socialized speech. The child's use of symbols frees him from dependence on immediate concrete objects, but the symbols are still mobile and personal. However, the use of symbols is the first step in the development of representative thought. As the child discovers the need to defend his actions and ideas to himself and others, he adapts and organizes his thought and speech to this end. Through repeated attempts to establish new levels of equilibrium, the child develops toward more sophisticated levels of logical, analytical thought characterized by the use of signs which, unlike the earlier symbol, have relatively fixed, interpersonal meaning. For Piaget, language is the vehicle which, through its interplay with the earliest forms of thought, enables the child to conceptualize the world around him, thus arriving at higher forms of representative thought.

Bruner. Bruner and his colleagues at the Harvard Center for Cognitive Studies have attempted to incorporate transformational grammar into a cognitive theory which in many respects resembles that of Piaget. Cognitive growth is ". . . the means by which growing human beings represent their experience to the world and . . . organize for future use what they have encountered [Bruner, Goodnow, & Austin, 1966, p. 1]."

Three major factors influence and guide cognitive growth: (a) the development of representation, (b) the impact of culture, and (c) the relationship of man's growth to his evolutionary history. In western culture, language permeates all three factors. Language acquisition is included in the broader development of representation; cultural transmission is effected largely through the medium of language; and through evolutionary history, language has become one of our most important and valued tools.

Development of representation follows three stages, the enactive (birth to one year), the ikonic (one to four years), and the symbolic representation period (four and above). During the enactive period the child learns about the world through his actions, while in the ikonic stage he acquires techniques of representation through imagery. Early in the ikonic period the child's imagery is closely related to his manipulation of objects, but by the end of this period he is able to "represent the world to himself by an image or spatial schema that is relatively independent of action [Bruner, Goodnow, & Austin, 1966, p. 21]." The child's imagery, like his visual perception, is diffusely organized, concrete, egocentric, marked by unsteadiness of attention, and organized around a minimal number of cues, but these characteristics are modified with the development of symbolic representation. Language frees the image from its spatial, temporal, and affective limitations.

Symbolic activity "stems from some primitive or protosymbolic system that is species-specific to man [Bruner, Goodnow, & Austin, 1966, p. 44]" and is manifested in language, tool-using, skilled forms of serial behavior, and the organization of experience. The first use of language involves the learning of arbitrary markers or names for the objects in the environment. Naming is accompanied by a primitive enactive form of categorization (e.g., the child places a pan in the kitchen cupboard showing that, in some sense, he has formed a class of "things that belong in the kitchen"). Meanings are gradually refined from early holophrastic speech (i.e., the use of single words to express complete sentences) enabling the child to organize his thought by means of superordinate groupings. Hence, the emergence of language is dependent on prior experience, but once language is established, it serves as an instrument to advance thought to higher levels. This is possible because "surplus meaning" may be read into experience in accordance with the built-in implications of the rules of language. Language enables a child to think about his thoughts, and to note contradictions between his perception and his linguistic representation of events. For example, in Piaget's well-known conservation experiment, a child may say: "This one looks bigger, but they are really the same," and can use this contradiction to grasp the concept of conservation.

The impact of the culture is seen in its predominant mode of representation. For an aborigine, the major mode is enactive as expressed in the work of farming and rituals of the dance. Bruner, Goodnow, and Austin (1966) point to differences in cognitive style between Mexican urban and rural children, and between Eskimo and suburban Boston children. The difference is "most completely described as a difference between abstractness and concreteness."

> We believe that the difference between the city child and the rural child derives from a differential exposure to problem solving and communication in situations that are not supported by context as is the case with, for example, most reading and writing [p. 315].

A technological society values abstracting abilities, and schools its children in their attainment. This achievement is possible only through the medium of language. Cognitive activity is a kind of information processing, and education is the learning of "technologies" which aid and direct cognition. Hence, the course of cognitive growth comes about not so much as a result of the individual's striving for equilibrium as in Piaget's theory, but rather through "the process of education."

Brown. For Brown (1958), the major processes in acquiring a first language are (a) the perception of linguistic categories, (b) the development of motor skills involved in pronunciation, (c) the formation of a generative grammar, and (d) the learning of referent categories. The central function of language is to make reference between linguistic and nonlinguistic forms. The nonlinguistic referents are classes or categories, not particular instances (e.g., "book" refers to a class of objects). Hence, in learning to apply names correctly, the child must learn to notice the distinctive characteristics of the members of a class, and to disregard the nonsignificant aspects. Much of this learning is prelinguistic. Even before the child speaks or understands language, he is learning about the environment by handling objects and observing his surroundings. Thus he forms concepts of such universals as space, time, and physical objects. The child, and later the adult, learns to use his knowledge of the environment to form the categories that correspond to names. Unlike the prelanguage universal concepts, later referent categories are of necessity culture bound, since words in different languages have different ranges of reference.

Brown cites evidence that, up to adolescence, children use classification strategies which are different from those of adults. Their notion of the relationship of subclasses to larger classes is imprecise. Being unable to subordinate a subclass to a larger grouping, they relate subclasses to one

another. They classify in terms of "chain complexes" (i.e.. to two objects which have a common characteristic is added a third object having a different characteristic in common with one of the first pair), rather than on the adult basis of a common denominator. Hence, although the formation of new reference categories goes on throughout the lifetime of the individual, it proceeds differently in childhood. For Brown, then, the model of language development is intimately bound up with the process of concept acquisition.

Research Literature on Cognitive Models

Piaget's theory has generated a vast body of research, most of it related to the validation of his stages of intellectual development as manifested through the appearance of such concepts as conservation of mass, weight and volume, number, class, moral rules, etc. The study of language in the context of this theory and the nature of the relationship between the linguistic and cognitive aspects of development have received less attention.

Egocentrism. As noted earlier, a central concept in Piaget's theory is the egocentrism of the child. To study the egocentric nature of early speech, Glucksberg, Krauss, and Weisberg (1966) devised a task requiring young children to develop verbal referents for communicating about novel forms. The results showed that pairs of nursery-school children were unable to converge upon a shared nomenclature for the novel form, though they performed better using phrases formulated by adults.

Egocentric speech, according to Piaget, falls out of the child's language system and is replaced by socialized speech. Vygotsky (1962) has hypothesized that egocentric speech becomes subvocal, but remains as a cognitive planning device. Kohlberg, Yaeger, and Hjertholm (1968) report that "private" speech is common among children four to six years of age, declines regularly thereafter, and is virtually absent in older children. The incidence of egocentric speech appears to reflect primarily the child's level of cognitive development, but also the functional demands of the situation.

The affective aspects of egocentric speech also receive some support in the research literature. Children's early speech does in fact often seem imbued with emotion. Leopold (1949b) believes that the first step in linguistic development occurs when a child attaches emotional significance to a sound produced accidentally. Meumann (1894) maintains that the child's first words express his "emotional relation" toward the objects and events referred to, and that this expressive aspect of children's speech maintains its dominating role for some time. Menyuk (1963b) also finds

support for this aspect of Piaget's theory in her study of children's syntactic structures.

Elkind (1970) has pointed out another aspect of egocentrism which has direct application to reading. According to Piaget, the preoperational child's perception and thought is "centered," that is to say, he can focus on only one aspect of a situation at a time. A young child whose perception is not yet decentered will have problems with field-ground effects, in this case with the discrimination of printed symbols. Elkind has designed a series of games to train perceptual skills, and has discovered that inner-city children's reading improves as a result of such training (Elkind & Deblinger, 1969). Centration also means that the child has difficulty in dealing with two elements at the same time. According to Elkind (1970), this may mean that the child is having difficulty dealing simultaneously with the shape and sound of the letter, the phoneme-grapheme relationship that Gibson and colleagues (1962) have indicated is an important feature in learning to read.

Language and thought. Furth and Milgram (1965, p. 322) experimented with deaf and retarded children in an attempt "to isolate conceptual operations from antecedent and subsequent verbal factors, and to assess the role and the interaction of such variables with age and mental ability in the solution of classification problems." Two major conclusions were that there is no evidence that verbal mediation is needed as a construct in cognition, and that the influence of language on cognition is indirect. Additionally, they suggest that the constant use of language exclusive of accompanying experiences is deleterious to the conceptual development of children deficient in language. In a study of the relative effects of language and perceptual experience on anticipatory imagery in water-level representation, Beilin, Kagan, and Rabinowitz (1966) found that perceptual training was more effective than verbal training.

Bever, Mehler, and Epstein (1968) refer to studies which support the hypothesis that young children have basic cognitive abilities but utilize them inefficiently.

Piaget and Inhelder (1969) reject the notion that syntactical rules are learned by imitating adult speech. Commenting on the work of Brown, Berko, and Ervin and Miller, they state:

> These studies . . . have shown that the acquisition of syntactical rules cannot be reduced to passive imitation. It involves not only an important element of generalizing . . . but also certain original structures [p. 85].

Menyuk (1963b) also finds support for this aspect of Piaget's theory in her work on children's use of syntactic structures.

Piaget further cites the work of Sinclair-de Zwart (1967) who found that as children's cognitive abilities develop they use linguistically higher-order structures. In fact, there is a fair amount of evidence which suggests that children have a grasp of syntactic and semantic structures long before these forms appear in their speech. De Laguna (1927) has argued that the earliest single-word utterances have the conceptual content of full sentences because they are comments on aspects of the situation in which the speech occurs, and make use of predication, a fundamental aspect of the deep structure (or meaning) of sentences. Predication is not the only relation evident in early speech. Within the span of the two-word sentence, children express direct and indirect objects, subject modification, and possibly possessives and prepositions. McNeill (1966a) has discussed the appearance of these relations in Japanese children, and Slobin (1970) has reviewed a number of diary studies and found evidence of the early emergence of the basic grammatical relations in seven other languages. The expression of complex ideas in single-word utterances is referred to as "holophrastic speech" (McNeill, 1970). It means that children's phonological ability is more limited than their ability to conceive the content of complete sentences. This content is often closely linked with action, in some cases almost fused with action. Leopold (1949b) records that at 20 months, his daughter said "walk" as she got out of a cart to walk, "away" as she pushed something away, and "blow" as she blew her nose. Taken as a whole, this evidence appears to suggest that certain grammatical distinctions are implicit in children's early speech before they actually appear. However, L. Bloom (1971) has recently raised some doubt on this issue.

Critique of Cognitive Models

Perhaps the greatest criticism of cognitive models is that they fail to account specifically for the facts of language development. It is not so much that linguistic facts are incompatible with the models as that they seem irrelevant to them. Yet the cognitive and language functions are interdependent, and their developmental paths are intertwined. It is difficult to see how a theory in either area can be considered adequate if it fails to take account of existing theories and facts in the other. Piaget's theory is probably the most comprehensive and interdisciplinary of the cognitive models and, as previously noted, he and his colleague Sinclair-de Zwart are attempting to incorporate linguistic data into the general framework of the theory.

Egocentrism. Egocentrism in thought and speech has proved a useful concept in accounting for early language. However, McNeill (1970, p. 1091) sees egocentrism as only a partial answer. For if a child were egocentric in Piaget's

sense, "one must wonder why he ever included subjects at all, since all subjects would appear to be 'understood' to an egocentric mind." McNeill believes that egocentrism plays a role, but it is secondary to the more fundamental role of extrinsic and intrinsic predication. Intrinsic predication includes definition, class membership, habitual activities, and self-evident qualities, while extrinsic predication states some attribute which is not an inherent quality of the subject. Both in English and Japanese, children tend to include subjects with extrinsic predicates and omit subjects with intrinsic predicates (Brown, Cazden, & Bellugi, 1968; McNeill, 1968) as though the information contained in an intrinsic predicate were felt to be inherently true. According to McNeill, it is possible that holophrastic utterances consist largely, if not exclusively, of intrinsic predicates.

Considerable dispute has revolved around the role of language in the emergence of concepts. While Piaget attributes prime importance to the individual's activity, and the presence of the requisite structures, Bruner maintains that if the child is to succeed in conceptual tasks, he must have some internalized verbal formula that frees him from his perceptual domination. Holt (1966) has questioned the conclusions drawn both by Piaget and Bruner from the experiments on conservation and other concepts.

> . . . there are some very important respects in which all children do grasp the principle of conservation, and this long before they talk well enough to learn it through words. Bruner says little children are fooled by their senses because they have no words to make an invariant world with. But the world they see, like the world we see, is one in which every object changes its size, shape, and position relative to other objects every time we move. It is a world of rubber. But even by the time they are four, or three, or younger still, children know that this rubber world they see is not what the real world is like. They know that their mother doesn't shrink as she moves away from them. And this is a far more subtle understanding than the ones that Piaget and others like to test.
>
> This is Bruner's "fundamental error--the idea that our understanding of reality is fundamentally verbal or symbolic, and that thinking, certainly in its highest forms, is the manipulation of those symbols" [p. 5].

Kohnstamm (1967), like Bruner, believes that verbal training is a valuable, if not essential factor, in the development of concepts. He finds Piaget's deemphasis on verbal learning incongruous in the light of the latter's insistence on minute verbal justifications as experimental checks. In fact, this verbal interchange may well be the stimulus for the child to begin thinking about the concept.

If language and thought are independent systems, as Piaget supposes, language becomes an unreliable indicator of the child's understanding. It may lead us to underestimate his grasp of a concept, as when a child or adult is able to apply his knowledge in practical situations without being able to express it verbally; or, we may overestimate the level of understanding, especially when a child is adept at manipulating verbal symbols. Flavell (1970), who is well known as an expositor and interpreter of Piaget, suggests that Chomsky's competence-performance distinction may be useful in discussing this question. A child may have a conceptual item early but in the ensuing years the item slowly frees itself from performance limitations, gradually becomes consolidated, stabilized, and generalized until it emerges as a reliably elicitable cognitive tool.

PSYCHOLINGUISTIC MODELS

Psycholinguistic models fall into three categories, all of which may have relevance for reading:

1. Phonological;
2. Syntactical;
3. Semantic.

McNeill (1970) describes phonology, syntax, and semantics as the three main components of grammar. He describes semantics as the "basement" of syntax and phonology as the "penthouse"; i.e., the most visible part of language (p. 1130).

Phonological Models

Phonological development refers to the emergence of rules for combining sound units (phonemes) into pronounceable sequences in a language and for relating such sequences to the surface structure of sentences. The most prominent theory in this area is that of Jakobson whose 1942 monograph, Child Language, Aphasia, and Phonological Universals, appeared in English for the first time in 1968. In this celebrated paper, the modern conception of the relation between linguistic universals and the development of language, which has played an important role in theories such as those of Lenneberg and Chomsky, was advanced for the first time. Jakobson argues that the sequence of phonemic development is invariant and universal among children. All children pass through the same steps, though the rate of advancement may vary. There is a striking similarity between phonemic and syntactic development. Both begin with a universal primitive form, which does not correspond to any language, but is so organized that it can become any language through a process of differentiation. The natural order of acquisition and distribution which

results from the latent universal structure appears to be the same in all languages. The first vowel to appear is a back vowel [a], and the first consonant a labial [p] or [m], thus allowing the first consonantal opposition /pa/ and /ma/ (with repetition, papa and mama).

Jakobson contends that the development of a phonemic system is the result of filling in the gap between the two initial phonemes /p/ and /a/ by a process of differentiation, which he describes in detail. At each step, new "distinctive features" are introduced. For example, from the initial /p/ there is a division of consonants into labial and dental, and /ta/ is contrasted with /pa/. These first phonemes constitute the "primary triangle," with two dimensions (compact-diffuse and grave-acute) along which differentiation takes place in a predetermined sequence (Jakobson & Halle, 1956). Phonemes that are relatively rare among the languages of the world or that embody subtle distinctions are the last to be acquired. "It is as if, when children must push farther and farther from the universal core of language, fewer and fewer languages force them to do so [McNeill, 1970, p. 1135]." Labov (1964) has illustrated this point in a discussion of the informal dialect of New York speakers. More recently, Jakobson's colleagues have rejected parts of the model and introduced further refinements. Fant (1967) retains the concept of distinctive features, but rejects the necessity of these being binary (e.g., voiced vs. unvoiced).

The "laws of irreversible solidarity" describe certain universal asymmetries in the phonemic system of all languages; e.g., a language may have front consonants only, or back and front consonants, but no language has only back consonants. Jakobson sees the same laws applying both to children's language acquisition and to the dissolution of language in aphasics.

The distinctive features are what ultimately differentiate morphemes from one another, and Jakobson is interested in the minimum number of distinctive features necessary for a listener to identify morphemes. His model of speech perception posits a hierarchy of factors which, in order of decreasing importance, are: perceptual, aural, acoustical, and articulatory (the latter carrying no direct information to the listener). In decoding the message received, the listener operates with perceptual data obtained from responses of the ear to the acoustical stimuli produced by the articulatory organs of the speaker. The speaker operates under certain constraints. He must select from a storehouse of language that he and the listener have in common. The listener can anticipate the "preconceived possibilities" in the word string. Hence, the efficiency of communication depends upon the use of a common code by the participants.

Fant (1967) would place more emphasis on the acoustical and physiological structure of speech. He suggests as a basic principle in sensory functioning that humans are especially sensitive to variations of stimuli in time and place, a principle which he sees as essential to a dynamic theory of speech perception. A fallacy of earlier models is that they have tended to use the principles of speech wave analysis rather than physiological principles. Fant calls for an intensified search for "auditory patterns" which have a physiological basis.

Two other co-workers of Jakobson, Stevens and Halle (1967), have proposed a recognition model of speech perception based on an active feedback process. They seriously question the validity of the notion that speech is perceived in discrete units. "It has become obvious . . . that, in actual speech events, the discreteness of the segments and the features is blurred or totally obliterated." We perceive speech, not in terms of physical events, but rather in "abstract representations of classes of events [Stevens & Halle, 1967, p. 90]."

Research Literature on Phonological Models

Jakobson's (1941) own cross-cultural studies have shown that speech begins with front consonants and back vowels regardless of the language to which the child is exposed. Ferguson (1964) also found that when adults use baby talk they replace later consonants by those acquired earlier (e.g., /t/ for /c/). Moskowitz (1969) studied the acquisition of phonology in two-year-olds and found that children learn some phonemic or feature contrasts in a differential way which may be related to the universal constraints described by marking conventions.

Some research generated by Jakobson's theory of distinctive features is related to perception, short-term memory, and learning. Wickelgren (1965) found that vowels are encoded in short-term memory, not as a unit, but as a set of two distinctive features (place and openness), each of which may be forgotten independently. In a later study, Wickelgren (1966) found that consonants are encoded in short-term memory as a set of distinctive features (voicing, nasality, openness, place), each of which may be forgotten at least semi-independently. Wickelgren cites Peterson and Barney (1952) and Miller (1956) to suggest that the same dimensions or distinctive features are involved in perception as in short-term memory.

Jenkins, Foss, and Greenberg (1968) found that subjects who used articulatory cues based on the distinctive features of sounds performed more effectively in paired-associate learning than those who were receiving cues based on sound and systematic relations.

Some authors have questioned the viability of the phoneme as a unit of speech perception. Denes (1963) finds that the characteristics of sound do not identify a particular phoneme uniquely. The ambiguities of sound are resolved by making use of the hearer's knowledge of linguistic and contextual constraints. We are able to make sound which has been distorted intelligible by using nonacoustic information. Miller, Heise, and Lichten (1951) found that subjects could identify words against a background of noise. At a sound-to-noise ratio where no nonsense syllable could be identified, nearly all spoken digits were identified. When whole sentences were presented, intelligibility was higher than for separate words.

Miller (1962) maintains that a cognitive unit involves a decision. It has been shown that a decision rate of one per sec. would equal about three words or one phrase (Warren & Gregory, 1958). Garrett, Bever, and Fodor (1966), on the other hand, concluded that "an immediate constituent" is a unit of speech perception. The question of the size of the unit of speech perception is apparently still open to question.

Critique of Phonological Models

In a review of Child Language, Aphasia and Phonological Universals, Luria and Leontiev (1969) hail Jakobson as one whose "creative spirit has stimulated the development of numerous branches of linguistics and whose novel and original approach to basic problems of language has won world-wide fame." His review of the progression from infant babbling to full-blown language is seen as a "dramatic story," and the use of clinical data from aphasics as a tool for speech analysis is described as "a new approach which deserves attention."

However, the same authors are critical of Jakobson's failure to emphasize the physiological aspects of aphasia, without which the analysis of aphasia is unproductive. His tacit assumption that phonemes serve the child as operative psychological units "hardly corresponds to the facts." As noted earlier, Fant (1967) has written on the same problem.

McNeill (1970, p. 1132) views the concept of distinctive features as "beyond doubt, one of the most useful in contemporary linguistics" and credits Jakobson with being the first to apply the concept of a linguistic feature to questions of language development. The finding that such features have cross-cultural validity also strengthens the concept of linguistic universals, which Jakobson first presented and which plays an important role in the theories of Lenneberg, Chomsky, McNeill, and others. However, the conception of distinctive features has been modified by Stevens and Halle who

find that the features are not discrete and that patterns are recognized according to pattern-generating rules against which the patterns under analysis may be matched.

Syntactical Models

Syntax is that part of grammar which has traditionally received most attention from grammarians. The beginnings of the study of children's syntactic structures go back to Rousseau, and traces of modern theories of generative grammar may be found in Preyer and Stern (Blumenthal, 1970).

Chomsky. Chomsky (1965) proposes a theory of syntax with far-reaching implications for the behavioral sciences. The theory is based on the proposed existence of universals in the human mind. In language these universals are manifested in the grammatical forms of sentences. They reflect an underlying, biologically based structure which is shared by all members of the species.

Chomsky's basic model concerns syntactic structure. This open-ended theory attempts to describe language in terms of grammar. Traditional grammars and probabilistic models of language assume that meaning is dependent on grammar. In Chomsky's model, what is grammatical is independent of what is meaningful. The model assumes an ideal speaker-listener who has perfect knowledge of the language and who carries in his head a set of generative rules which constitute the transformational stage, the central factor in the tripartite structure of the grammar. This tripartite structure includes deep structure, transformational rules, and surface structure. The deep structure of a language defines, through transformational rules, the meaning and interpretation of a language. It is abstract and is not represented in speech. Furthermore, as Chomsky (1968) writes:

> The rules that determine deep and surface structure and their interrelation in particular cases must themselves be highly abstract. They are surely remote from consciousness and cannot be brought to consciousness [p. 283].

A kernel sentence is an aspect of the deep structure; that is, the kernel sentences could be said to represent the various acceptable strings to which the transformational rules are applied. Although linguists are unable as yet to describe completely the deep structure, it can be said that kernel sentences, or an abstract grammatical form, are stored in memory with footnotes to transform the sentence in whatever way is necessary. These transformational rules are considered to be universal.

The rewrite rules of deep structure are in the form A Z/X-Y. A is a single-category symbol and Z is a normal string of symbols (such as a phrase or sentence). A category is a part of speech or a functional part of speech. This rule is interpreted as asserting that the category A is realized as the string Z when it is in the environment consisting of X to the left and Y to the right. This system of rewrite rules can be expanded indefinitely to describe the entire grammar of the language.

Residual notions, such as action nouns vs. count nouns, may be explained in the theory through use of some kind of scale of grammaticalness. Such a scale would be able to account for those sentences that are grammatical but not meaningful such as: The dog looks barking.

In brief, Chomsky finds that a theory of linguistic structure that aims for explanatory adequacy must contain:

1. a definition of "structure description";
2. a universal phonetic theory that defines the notion "possible sentence";
3. a definition of "generative grammar";
4. a method for determining the structural description of a sentence, given a grammar;
5. a way of evaluating alternative proposed grammars.

But the theory of syntax is also a theory of language acquisition. Chomsky (1965, pp. 30-31) describes the basic things a child capable of learning language must have:

1. a technique for representing input signals;
2. a way of representing structural information about these signals;
3. some initial delimitation of a class of possible hypotheses about a language structure;
4. a method for determining what each hypothesis implies with respect to each sentence;
5. a method for selecting one of the (presumably, infinitely many) hypotheses that are allowed by (3) and are compatible with the given primary linguistic data.

Chomsky has described the process of language acquisition as a "kind of theory construction" in which "the child discovers the theory of his language with only small amounts of data from that language." This "theory of language" is predictive; that is, the child responds to the linguistic data that he receives so as to form generalizations about language, which are reflected in his speech. Chomsky emphasizes that the process is much more than pure imitation, as may be seen from the child's production of novel sentences. The child's activity is dependent on innate restrictions on the form of

grammar. Chomsky (1968) states that: "The restriction on the form of grammar is a pre-condition for linguistic experience and it is surely the critical factor in determining the course and result of language learning [p. 284]." The fact that children can communicate meaning, the most abstract part of language, before they have acquired the grammar seems to call for some explanation. Chomsky (1957, 1965) introduces the concept of a language-acquisition device or LAD, which takes the body of speech utterances to which the child is exposed and somehow constructs from it a grammatical theory.

Thus, the child uses the language universals which he possesses at birth to construct an internal picture of the syntactic structures around him. He learns the ideal theory. The precise nature of the interaction between the linguistic environment and the child is unclear, as is the degree of "activity," mental or otherwise, necessary for this achievement.

> We must also bear in mind that the child constructs this ideal theory without specific instructions, that he acquires this knowledge at a time when he is not capable of complex intellectual achievements in many other domains, and that this achievement is relatively independent of intelligence or the particular course of experience [Chomsky, 1968, p. 284].

McNeill. McNeill (1966b, 1968a, 1970) adopts a nativistic thesis in an attempt to deal with the "fundamental problem . . . that language acquisition occurs in a surprisingly short time. . . . Thus a basis for the rich and intricate competence of adult grammar must emerge in the short span of 24 months [1966b, p. 15]." To explain this phenomenon, he borrows from Chomsky (1961, 1965) and Katz (1966) the concept of a language-acquisition device (LAD) which has the randomly received corpus of speech around it as input and grammatical competence as output. The internal structure of LAD is given by the linguistic universals, which are of two types: (a) formal (e.g., grammatical rules), or (b) substantive (e.g., the hierarchy of categories). Equipped with these universals "LAD operates something like a scientist constructing a theory," formulating, testing, and discarding hypotheses. "Thus the universals guide and limit acquisition [1966b, p. 39]." Having universals enables the child to progress step by step toward adult grammatical classes, starting with the simple dichotomy of open and pivot classes and proceeding to later grammatical distinctions "in an order determined by the hierarchical arrangement of categories." McNeill distinguishes two components of LAD, one which analyzes and transforms the incoming speech data, the other comprising a body of linguistic information (e.g., that there are sentences, that sentences include noun and verb phrases, etc.), information which is universally applicable to any language.

McNeill distinguishes between "weak" linguistic universals, which are dependent on universal cognitive abilities, and "strong" linguistic universals where uniquely linguistic capacities are required. He is obviously more attracted by the latter. (However, Fillenbaum [1971, p. 261], states that McNeill, "after some vacillation," no longer finds the distinction valid.)

Slobin. Slobin (1966a, p. 87), while sympathetic to the model set forth by McNeill, finds the proposal of a significant innate component in language acquisition to pose a problem; namely, "how to determine just what sorts of things should be considered 'preprogrammed'?" McNeill views the child as born with the entire set of linguistic universals which he uses as a grid through which to filter language input.

> McNeill takes a "content approach" to LAD, while I would favor a "process approach." It seems to me that the child is born not with a set of linguistic categories but with some sort of process mechanism--a set of procedures and inference rules if you will--that he uses to process linguistic data. . . . The linguistic universals, then, are the result of an innate cognitive competence rather than the content of such a competence [pp. 87-88].

Thus, language acquisition is subsumed under the more general rubric of cognitive development; that is to say, the development of language is controlled by the development of cognitive abilities such as memory storage, information processing, etc., which increase with age. In fact, the "preprogramming" may consist simply of the ability to learn certain conceptual and semantic categories and to understand that these are the basis for grammatical structures. These learnings are not explicit, but are manifested in behavior. "To qualify as a native speaker . . . one must learn . . . rules. . . . This is to say, of course, that one must learn to behave as though one knew the rules [Ervin-Tripp as quoted in Slobin, 1971b, p. 55]." Thus, Slobin favors a cognitive learning approach, which retains the innate species-specific factor as a system of broad intellectual potentialities and places the substantive aspects of language clearly in the domain of learning. Like other cognitive theorists, he sees the organism as an active participant in this learning, but maintains that "as yet, we have a very limited understanding of the psychological and physiological mechanisms underlying these achievements [1971b, p. 66]."

Research Literature on Syntactical Models

Research following Chomsky and the other models that are an off-shoot of his theory may be considered in the following three categories relating to:

1. The psychological reality of the model (usually referred to as "the correspondence hypothesis");
2. The competence-performance factor in the grammars of children;
3. The patterns in children's grammars and the sequence in which their grammars are acquired.

The correspondence hypothesis. An early question stemming from the theory of generative grammar centered around the psychological reality of such grammatical features as transformations and phrase markers. According to the correspondence hypothesis, the relative difficulty a subject experiences in understanding a sentence (i.e., translating it into deep structure) should be correlated with the number of grammatical rules necessary for its derivation. Early experiments seemed to provide impressive evidence of a direct relation between the complexity of the transformation and the complexity of the psychological processes involved. Miller, McKean, and Slobin (1962) found a relationship between the time required to match pairs of sentences and the number of transformations necessary to change one form to the other. Gough (1965) also verified that active transformations are speedier than passive transformations. Slobin (1966b) has found that more time is needed to evaluate negative than passive transformations, or passive than kernel sentences. McMahon (1963) found that passive sentences took longer to process than active sentences and negative sentences longer than nonnegative sentences. In addition, he found no interaction between passivity and negativity. Mehler (1963), Mehler and Miller (1964), Savin and Perchonok (1965), Turner and Rommetveit (1967), and Huttenlocher, Eisenberg, and Strauss (1968) have added further support to the psychological reality of transformations.

Brown and Hanlon (1970) studied derivational complexity based on the number of operations needed to make the transformations, rather than the number of rules. The complexity of one transformational rule, they argue, is not necessarily equal to that of another. They successfully predicted the sequence in which grammatical constructions would appear in children's speech, based on a hierarchy of derivational complexity.

Fodor and Bever (1965) conducted a study to determine the psychological reality of phrase markers. Ss perceived clicks produced in conjunction with spoken language as occurring at major syntactic breaks in the sentence, whether or not they did in fact occur at those times. Garrett, Bever, and Fodor (1965), using the same technique but controlling for the effects of acoustic variables (pauses and intonation), found that the differences in responses could be predicted by the constituent structure of the sentence. However, there have been other studies which cast some doubt on these

findings. A study by Fodor and Garrett (1967) suggests that any model of speech perception which assumes that the operations of the grammar are identical with the recognition device should be viewed with "some suspicion." They found that the correspondence hypothesis could not account for, but rather contradicted, the results they obtained (e.g., relative pronouns facilitated perception; adjectives did not add to complexity). This less rigid view considers that we perceive language in units related to grammatical structure but not necessarily equated to the rules of the generative transformational grammar. Ladefoged and Broadbent (1960) substantiated the hypothesis that the units on which the decoding process operates are larger than single speech sounds.

A study by Mehler and Carey (1967) provided some evidence for the psychological reality of the abstract properties of speech stimuli (i.e., deep structure). Ss' perception of sentences mixed with noise were evaluated. Their errors showed that they often select words that are compatible with syntactic set rather than with words phonetically close to the stimulus. Changes in both surface structure and base structure can significantly disrupt perception. A recent series of experiments by Reber and Anderson (1970) cast doubt as to whether there is any relation between the way subjects perceive clicks and the psychological reality of phrase markers. In one study adapted from that of Fodor and Bever (1965) they found syntactic and semantic factors to be irrelevant in their effects on the perception of clicks in messages. They concluded that nonlinguistic factors, such as attention, memory, and response biases, were primarily responsible for errors made in trying to locate clicks in messages.

Johnson (1965) studied errors made in the recall of sentences. He found that the probability of an error was greater at transitions from one phrase to another than within phrases. Results could be explained by assuming the perceptual unit for encoding the language was some order of the phrase-structure rule.

Levelt (1970) had Ss listen to sentences embedded in white noise. His analysis of their responses indicated the existence of a hierarchial chunking process in our perception of sentences. Large chunks tend to coincide with major constitutents.

Bever (1970) takes a different view of the adult perception of language. He describes the strategies used as: isolating and relating the lexical sequences, relating clauses according to semantic construction, and identifying the actor-action and object in the sentences. He sees these strategies, rather than that of performing transformations, as constituting the adult's perception of speech.

Fodor's (1969) remarks regarding the correspondence hypothesis reflect a point of view current in the field of linguistics:

> Grammatical rules are themselves not a part of the recognition procedure. . . . The mental operations which underlie the behavior of the speaker/hearer are not identical to, and probably do not include, the grammatical operations involved in generating sentences.

He does, however, state that "the relation between linguistic and psychological models will have to allow for the possibility of quite abstract mapping of grammar onto any model of the speaker/hearer." Slobin (1971a, p. 37) reaffirms that view when he states that "we cannot hope for simple metrics of the difficulty involved in processing sentences on the basis of their syntax. . . . They are used as syntactic and semantic and pragmatic entities" as well.

Competence vs. performance. Contemporary linguists deny that a theory of competence can ever be constructed from studies of linguistic productions (Chomsky, 1964). Distributional analyses describe a child's grammatical classes and give some hints as to his grammatical rules. A theory such as Chomsky's enables the experimenter to go far beyond this. He may exploit the fact that adult grammar is the end point of linguistic development and judge whether there is sufficient evidence in the child's productions to justify ascribing it to him. Thus, to cite only a few studies, Bellugi (1964, 1967) studied the development of negation; Klima and Bellugi (1966), questions in the child's speech; Ervin (1964), the child's knowledge of English plurals; Berko (1958), plurals and past tense. The competence-performance distinction calls for interpretation of productions. For example, does the fact that the child systematically excludes auxiliary verbs from his speech signify that they are absent from his grammar, or does it indicate simply the constraints of a limited memory span? Such questions can be answered only by testing for comprehension.

Brown (1957) showed that nursery-school children have semantic correlates for certain grammatical classes. Fraser, Bellugi, and Brown (1963) and Lovell and Dixon (1967) have used an Imitation, Comprehension, and Production Test with 3- and 2-year-olds, respectively. Shipley, Smith, and Gleitman (1969) studied comprehension in children as young as 18 months by giving them commands and observing whether the commands were followed. Bever, Mehler, and Valian (1967) used some commands containing only words known to a child and others containing unfamiliar words. Slobin and Welsh (1967) have used imitation to study comprehension rather than production. In this case, the child is not required to reproduce the model's sentence verbatim but to recover its deep

structure. All these studies point to the validity of the competence-performance distinction, but they suffer from the common limitation that not every aspect of syntax can be tested via a corresponding activity.

The acquisition of grammar. The literature on the development of various grammatical categories is quite extensive and has been reviewed elsewhere (Ervin and Miller, 1963; Ervin-Tripp, 1966; Ervin-Tripp & Slobin, 1966; McCarthy, 1954; McNeill, 1970; Slobin, 1966c; Slobin, 1971a).

Critique of Syntactical Models

Chomsky's model has not only generated a great deal of research on related issues, but has enabled linguists to place the atheoretical studies which abounded prior to 1950 in theoretical perspective. In addition, it has provoked elaboration and counter-proposals like those of McNeill and Slobin. Taken together, these facts indicate in some measure the revolution that has taken place in psycholinguistics over the past decade. These authors, and many others, have presented a formidable array of evidence pointing out the inadequacy of behaviorist learning theory to account for the phenomena of language.

Psycholinguistic models themselves have not escaped entirely unscathed, however. In particular, the nature of linguistic universals has been the subject of considerable debate. McNeill, it may be remembered, viewed the remarkable rapidity of language acquisition as pointing to the existence of innate linguistic properties. Fraser (1966) has retorted that the "astonishing speed" of language acquisition commented on frequently by linguists is less astonishing if we consider that the child is working constantly on acquiring language from birth to the age of six or beyond. The "mere exposure," which McNeill discounts as the medium for learning, actually exposes the child to the relational communication which occurs between adults and children. Fraser also suggests that instead of arguing about the nature of innate capacities, we should get on with the job of discovering what the language behavior is that the innate capacities and mechanisms are supposed to be explaining. It has already been noted that Slobin (1966b) rejects McNeill's adoption of "strong" linguistic universals and, indeed, one may argue against ascribing the recognition of all linguistic features to some innate capacity on the ground that it ignores the role of learning, and especially learning through feedback. Granted that language is a unique function, there is no reason to suppose that the general laws of learning fail to apply. The fact that they cannot explain all the phenomena of language does not imply that the rules of grammar are necessarily preprogrammed.

Part of the problem is that the mechanism by which LAD performs the functions assigned to it is not entirely clear. To quote Slobin (1966b):

> McNeill . . . does not seem to speak to the question of why ontogenetic change in language performance is gradual; why it is that some grammatical categories are late to emerge. One reason could be--at least with regard to the substantive categories--that if the distinctions are semantic, they require varying amounts of experience to be learned. Another explanation could be that the child comes equipped with a set of hypotheses or inference rules that vary in their saliency and simplicity and that the child begins by trying out the more salient or simpler hypotheses [p. 90].

As yet, the field of psycholinguistics is unable to point to a clear choice among these (or additional) alternatives.

Fodor (1966), likewise, prefers to regard the structure which a child brings to language learning as "intrinsic" rather than innate. He has written:

> In short, a comparison of the child's data with a formulation of the linguistic information necessary to speak the language the child learns permits us to estimate the nature and complexity of the child's intrinsic structure. If the information in the child's data closely approximates the linguistic information he must master, we may assume that the role of intrinsic structure is relatively insignificant. Conversely, if the linguistic information at which the child arrives is only indirectly and abstractly related to the data provided by the child's exposure to adult speech, we shall have to suppose that the child's intrinsic structure is correspondingly complex. We have already seen that the two limiting theories can be dismissed with some confidence. On the one hand, it is inconceivable that the child's data contribute no linguistic information, for this would mean that all such information is intrinsic. On the other hand, it seems that the data cannot contribute all the relevant information, for this would be logically incompatible with the fact that the child eventually learns to deal with utterances of sentences he has not previously encountered. It appears that the theory we want must lie somewhere between the two [p. 107].

The adult speech which the child hears is not random; it exhibits formal relationships among the utterances (e.g., answers to his questions) and usually corresponds to certain nonlinguistic events. Fodor's suggestion is that the child brings to language learning a set of rules that lead him to

infer from these formal relations the possible range of underlying syntactic structures.

Deep structure. Among the linguistic universals which have received criticism is the distinction between deep and surface structure. Olson (1970), for example, points out that Chomsky's formulation of the relation between syntax and semantics led him to assume that grammar was "autonomous and independent of meaning" and also primary, in that meaning could not be assigned until the sentence had been grammatically structured. Olson finds existing theories of word-referent relations inadequate, but advances a theory of reference in terms of a cognitive theory of semantics. A semantic decision, such as the choice of a word, is made in terms of the information the speaker believes the hearer needs to distinguish an intended referent from some perceived or inferred set of alternatives. From this point of view, the postulation of deep structure becomes unnecessary. To quote Olson (1970):

> If the functions usually attributed to the deep structure, such as the semantic component and the effects of syntactic selection restrictions, can be accounted for without implicating the deep linguistic structure, there remains little virtue in postulating such a level [p. 272].

McCawley (1968), on the other hand, has argued that deep structure is not enough, that there is no justification for assuming an autonomous level of deep structure, and semantics must be generative not simply interpretive.

Semantic Models

McNeill (1970, p. 119) characterizes this as the most pervasive and least understood aspect of language acquisition --pervasive because it has repercussions in wide areas of cognition, little understood because linguistic theory has given few guidelines for exploration. A discussion of Osgood's theory of meaning appeared in the section on behaviorist models, and will not be repeated here.

Goodman. Goodman (1968) is particularly concerned with the application of psycholinguistics to the reading process. Without going into the specifics of reading, we can extract the pertinent points that Goodman makes about children and language.

Words exist only within the flow of language. Neither words nor morphemes can be defined, pronounced, or classified outside of this language stream of varying intonation, pitch, stress, and juncture. Goodman's (1965) study showed that primary-school children may be unable to decode words in isolation but are able to read the same words successfully in a

running context. When given a list of words to learn, children were "calling names," a procedure more difficult than reading. Syntactic context is essential in both language learning and reading. Recognition of individual words only contributes to comprehension of meaning. Total comprehension involves reactions to several signal cores, such as: order of words (syntax pattern), intonation, inflection, and certain key functions that words play (pattern markers).

A child already knows these systems, which operate in the perceptual process of knowing language, by the time he begins to read. His knowledge of the structural system of the sound and grammar he uses in speech sets up certain expectations that strongly influence his perception. When this basic knowledge is recognized by instructors, it will be seen as forming the linguistic basis of perception in reading. Thus, Goodman views the reading process as "a psycholinguistic guessing game" in which thought and language interact. According to his model, the reader fixes at a point and begins a selection process. He picks up graphic cues based upon prior choices, language knowledge, cognitive styles, and learned strategies. From what he sees and from what he expects to see, he forms a perceptual image; then he searches his memory for matching syntactic, semantic, and phonological cues. He may then select more graphic cues or reform the perceptual image. Here the reader makes a guess or tentative choice, stores the extracted meaning in his short-term memory, and continues reading. If a guess is not possible, he checks his recalled input and tries again. Then he can make a choice based on decoding or, if this is still not acceptable semantically or syntactically, he can regress until an acceptable choice is made, and reading continues. Basically, proficient readers decode directly from the graphic stimuli and then encode from the deep structure. Improvement in reading skill, according to Goodman, is not due to greater precision but to better sampling techniques, greater control over language structure, broadened experience, and increased conceptual development, which make more accurate first guesses possible.

Although Goodman's model is based upon adult readers it does have implications for the teaching of reading. Goodman's work on the oral reading of beginners indicates that it is wrong to emphasize exact recitation of the graphic stimulus since this does not really indicate that the child understands what he is reading. As a child reads, he can extract correct meaning without voicing the precise morphemes or phonemes.

Ruddell. Ruddell (1970) has proposed a systems communication model, including use of language, perception, and reading. It is based on his division of language into the following three levels: (a) the "surface level" includes morphemic and syntactic components; (b) the second level,

"interpretation," includes structural and semantic components; and (c) the third level, "deep structure," includes integration and storage. Ruddell's model assumes the reality of surface structure, language processing through structural and semantic readings, deep structure, short- and long-term memory, feedback mechanisms, and the importance of affective mobilizers and cognitive strategies. According to this model, reading is

> complex psycholinguistic behavior which consists of decoding written language units, processing the resulting language counterparts through structural and semantic dimensions, and interpreting the deep-structure data relative to an individual's established objectives [p. 239].

Ruddell points out two important aspects of a child's language development. First, he states that a child's ability to comprehend <u>oral</u> or written language seems to be a function of his ability to see relationships among elements in a sentence. He cites Strickland's (1962) evidence that children who use movables and subordination in oral language are better at reading these features. Second, Ruddell's (1965) study of fourth-graders' oral language patterns compared to written patterns in their reading texts reveals that the children's reading-comprehension scores were significantly higher for passages reflecting their oral patterns of speech than for those passages that differed from oral patterns.

This model implies that as children develop cognitive strategies they are able to use alternatives to decoding words. For example, they may use high-order clues at the morphophonemic-morphographemic level or use feedback from the deep structure of the sentence to derive meaning. An important implication of Ruddell's work is that the child's linguistic development must be carefully appraised and, if necessary, specifically improved before he can be expected to achieve effective communication in speaking or reading.

<u>Brown</u>. E. Brown (1970) proposes a model of the reading process related to recent work in psycholinguistics. He contends that research into the acquisition of reading which emphasizes learning principles is misconceived. Learning, in its classical sense as a configuration of dynamic variables underlying a more or less unitary process, may not be the central factor in reading. Instead, he postulates that reading is far more intimately related to a <u>necessary</u> substratum of normal oral language development having to do more with biological maturation than learning. His model is an elaboration of Chomsky and Halle's (1968) outline of the process of reading aloud with certain analysis-by-synthesis modifications. The text is scanned with semantic and syntactic expectancy; words and short phrases are recognized through a word-filter device and stored in short-term memory in the form of abstract

articulatory features. The abstract set of symbols is checked for punctuation to determine where to segment the text. If the input is not compatible with the most recently generated surface, a heuristic analyzer searches the contents in short-term memory for clues to the various deep-structure strings that will generate the sequence. It identifies the logical subject and main verb, paying special attention to the analysis of verbs, and attempts to recover the deep-structure phrase-marker configurations. The most probable hypothesis is first projected, but if blocking occurs, an error message signals the generation of another deep-structure hypothesis. At this point, the reader determines whether or not the utterance is comprehensible, and may decide to recycle through the entire procedure.

Research on Semantic Models

Goodman (1970) points to a misconception of the reading process that persists because it appears to be a common-sense view. In its simplest form, this states that reading involves precise, detailed, sequential perception and identification of letters, words, spelling patterns, and large language units.

> A common misconception is that graphic input is precisely and sequentially recoded as phonological input and then decoded bit by bit. Meaning is cumulative, built up a piece at a time in this view. This view appears to be supported by studies of visual perception that indicate that only a very narrow span of print on either side of the point of fixation is in sharp focus at any time. We might dub this the "end-of-the-nose" view [p. 265].

In oral reading, there are three possibilities: (a) the reader may recode graphic input as oral language, and then decode it; (b) he may recode and decode simultaneously; or (c) he may decode first and then encode the meaning as oral output.

According to Goodman, his research suggests that readers who have attained a degree of proficiency decode directly from the graphic stimulus, and then encode from the deep structure; i.e., they apprehend the meaning of the phrase or sentence without necessarily reconstructing each word occurring in it. This feat is possible because readers utilize not one but three kinds of information simultaneously. He writes:

> Certainly without graphic input there would be no reading. But the reader uses syntactic and semantic information as well. He predicts and anticipates on the basis of this information, sampling from the print just enough to confirm his guess of what's coming, to cue more semantic and syntactic information. Redundancy and sequential

constraints in language, which the reader reacts to, make this prediction possible [p. 266].

Although the beginning reader needs more precise graphic information than the proficient reader, there is evidence that first-graders begin to draw on syntactic and semantic information almost from the beginning (Goodman, 1970). Holmes and Singer (1966) and Singer (1964) have found "word sense" (i.e., the ability to use contextual clues to fill in gaps in a passage) to be a significant variable in distinguishing between good and poor readers at all grade levels.

Ruddell (1970) has assembled a wealth of evidence in support of his model, including research on the processes of decoding and comprehension, as well as the affective and cognitive dimensions. The interested reader is referred to Ruddell's 1970 paper.

Critique of Semantic Models

The models included here have the advantage, in the present context at least, that they refer directly to the reading process and are psycholinguistic models of language as it functions in a more comprehensive reading model.

Goodman's model is important because it emphasizes the element of meaning which is often lost sight of in perceptual or component-skills models. Extracting meaning from the printed page is the essence of reading, but even the fluent reader sometimes fails to grasp what he is reading if his attention is elsewhere, even though he has decoded all the words. He has perused the material, recognized it as grammatical and meaningful, but in some way has failed to assimilate it into his deep structure. We need to understand more fully the nature of this assimilation process, and Goodman's model is a step in the right direction.

Ruddell's model is one of the most comprehensive, encompassing as it does considerations of grapheme-phoneme correspondence, short- and long-term memory, linguistic and nonlinguistic meaning, transformational and rewrite rules, feedback mechanisms, affective mobilizers, and cognitive strategies. It capitalizes on recent significant developments in the field of psycholinguistics, and is one of the few models to apply these developments to the psychological and educational aspects of reading.

INFORMATION-PROCESSING MODELS

Information-processing theory is being used in psychology and linguistics for the development of models and

simulation procedures. Basically, information processing is the quantification of information into "bits." Each bit of information reduces the state of uncertainty of the subject or program. Information theory operates within an open system which has as its components an input system, channel capacity, a storage system, programs for coding information to be stored, and an output system. Open systems contain subsystems, which can be compared to a human being's memory capacity or storage.

A general view of the models of human information processing is outlined by Norman (1970) in the following way:

> Newly presented information would appear to be transformed by the sensory system into its physiological representation (which may already involve a substantial amount of processing on the initial sensory image) and this representation is stored briefly in a sensory-information storage system. Following this sensory storage, the presented material is identified and coded into a new format and retained temporarily in a different storage system, usually called short-term memory. Then, if extra attention is paid to the material, or if it is rehearsed or organized, the information is transferred to a more permanent memory store (or, in some models, the rate at which it decays decreases substantially). In general, long-term memory capacity is so large that stored information must be organized in an efficient manner if it is to be retrieved. Decision rules must be used to retrieve information both to decide how to get access to desired information and exactly what response should be made to the retrieved information [p. 2].

Feigenbaum (1963, p. 297) has set forth the general assumptions of information processing models as follows:

1. The models represent mental processes and are psychological models of mental function. No physiological or neurological assumptions are made.
2. These models conceive of the brain as an information processor with sense organs as input channels, effector organs as output devices, and with internal programs for testing, comparing, analyzing, rearranging, and storing information.
3. The central-processing mechanism is usually assumed to be serial.
4. The models use a basic symbol of information called a "bit."
5. The models are generally deterministic, not probabilistic.

Miller (1969) suggests that ". . . psycholinguists should try to formulate performance models that will

incorporate . . . hypothetical information-storage and information-processing components that can simulate the actual behavior of language users [p. 268]."

In his classic paper, "The magical number seven, plus or minus two," Miller (1956) suggested that the limit of human memory is related to a general restriction on human information-processing capacity, memory being organized in what he called "subjective organization of input." Using the limit of items that an individual can remember, Miller proposed the "chunking" hypothesis. The seven items may be chunks or categories within which an individual stores and remembers other items, thus enabling him to increase the amount of information that each item contains until the seven original items are subdivided into a large number of smaller items. Retrieval of this information is determined by rules. Items are always "available," but not always "accessible," so rules or concepts must be established in order to retrieve any single item.

Yngve. Yngve (1960) programmed a digital computer to construct relatively simple sentences by using a basic descriptive model of English. The computer makes random choices of words as it progresses through a finite number of grammatical rules and constraints. Although the sentences are syntactically correct, they do not always make sense semantically.

When the computer program begins a construction (such as the subject of a sentence), it stores a remembered "node," such as a predicate, so that the second part will be appropriate for the first. If nodes precede the subject, they are "regressive structures" and must be stored in temporary memory. The programmed memory is limited to a depth of seven such words in order to accommodate the regressive steps. In accordance with English patterns, only two or three regressive steps are allowed (as in Yngve's "The family the woman we met yesterday told us about is leaving tomorrow") and the methods of the English language for meeting this depth restriction can be analyzed.

Yngve gives the following methods for making natural language easier to use: (a) use of alternative means of expression allows us to place the "light" construction first and the "heavy" construction second as in the sentence "He gave her the candy he got in New York while visiting his parents between Christmas and New Year's." That way the sentence starts with one less item in the temporary memory than in the sentence "He gave the candy he got in New York while visiting his parents between Christmas and New Year's to her"; (b) word building (up to a certain point) as in "rebuild" instead of "to build again."

The depth hypothesis (Yngve, 1961) indicates that the English speaker tends to produce sentences that keep the

"depth" at a minimum. This hypothesis can be used to explain compound words, structural reversal, and passive construction. By use of this program, Yngve concludes that we organize our natural language for the purpose of expressive power and for the purpose of limiting the strain on our memory.

Mandler. On the problem of accessibility, or information retrieval, Mandler (1967) described three types of rules or cues for the retrieval or output of encoded or stored information.

1. Associative cues are analogous to the associationist view of learning. These rules are specific to particular situations and include specific rules or labels related to associative cues (e.g., the ability to recall a person's name by remembering that you met at a particular place). "Associative cues also include special mnemonic devices such as idiosyncratic images, short-term abbreviations of long lists, labels, and similar cues or rules . . . specific to a particular output [p. 27]."

2. General accessibility rules can be applied to a variety of different situations. Examples are in the organization of serial lists and in the use of a categorial schema to draw words from storage. An "output program" is activated before any item is retrieved from storage. The output would reveal the organization of storage into superordinate and subordinate categories [p. 28].

3. Generative rules of information accessibility make it possible to produce novel material instead of exactly reproducing previous input. The generative theory in language has two sets of elements: (a) rules, transformations, or programs (syntax) and (b) vocabulary units (semantics). In language the syntactic rules are applied to words in storage in order to generate sentences and intelligible speech [p. 16].

Mandler points out that Selz (no reference given) has suggested that the human mind can be viewed as being equipped with a set of operations that are applied to materials. Newell, Shaw, and Simon (1958) note the parallel between Selz's view and the operation of digital computers.

Simon and Kotovsky. In the Simon-Kotovsky (1963) simulation program, it is supposed that subjects solve conceptual problems by developing a "pattern description" of the sequence of a given series problem and then using the description to generate the next member of the series. The program's task is to uncover the basic periodicity of the pattern and then the details of the pattern by detecting relations within or between periods. When this is found, it becomes a generative

rule and is used by the program to extrapolate the next element.

In their next experiment, a computer was programmed with the letters of the alphabet and then given test problems containing Thurstone's Letter Series Completion Tests. These letter series vary widely in difficulty and involve short-term memory for keeping track of at least two symbols simultaneously, and in some cases, two variable alphabetic sequences (forward and backward). The authors' central hypothesis was that subjects (or programs) attain a serial-pattern concept by generating and fixating a pattern description of that concept. Information theory proposes a list-processing language which "is a system of processes for acting upon symbolic information represented in the form of lists and list structures or lists of lists [p. 539]." Its processes include writing a symbol, copying a symbol, finding the adjacent symbol on a list, and modifying lists by inserting or deleting symbols. The authors postulate that ". . . normal adult human beings have stored in memory a program capable of interpreting and executing descriptions of serial patterns. In its essential structure, the program is like the one . . . described [p. 539]." Considering the high-level intellectual task involved in using generative rules, the program performed well compared to human subjects. The authors concluded that their ". . . theory provides a tenable explanation for the main pattern-forming and pattern-extrapolating processes involved in the performance of the letter-series completion task [p. 545]."

Newell, Shaw, and Simon. Newell, Shaw, and Simon (1958) developed the Logic Theorist Program (LT) in which a computer is programmed to use heuristics to aid and guide its search process for problem solving. On the use of programs in theorizing about certain levels of human or program performance, the authors state, "an explanation of an observed behavior of the organism is provided by a program of primitive information processes that generates this behavior [p. 151]." They believe that digital computers can be programmed to execute the same sequences of information processes that humans execute in problem solving. LT proved to be highly successful in discovering and using proofs for theorems in elementary symbolic logic. As a result of this experiment, the authors were led to summarize some of LT's "human characteristics" as follows: (a) Set. A preparatory set in LT allows it to save time in later stages by first checking through its list of axioms and computing a description of each for later use in its similarity searching process. Directional set gives the program a sequential process for applying different methods to problem solving (as use of substitution, then chaining, etc.). If problems are presented to LT in appropriate sequences, the program can utilize its early learning for later problems. (b) Insight. LT's success in solving difficult problems is due to its ability to use problem

structure as a guide instead of casual trial and error. The authors state,

> to approach a problem "meaningfully" is to have a strategy that either permits the search to be limited to a smaller subspace, or generates elements of the space in an order that makes probable the discovery of one of the solutions early in the process [p. 160].

The program uses a combination of trial-and-error search, experience, and cues in the problem-solving process. (c) Concepts. The program uses concepts in problem solving when its routine for describing and searching for theorems "similar" to the problem is called into action. All theorems which have the same description make up a common concept. (d) Hierarchies of Process. After LT searches its lists for theorems with the same description as the one presented, its description-computing program divides into a program for computing the levels in the expression. It also divides into a program for computing the number of distinct variables and also the number of "argument places" required for proof (p. 162).

LT also generates a second hierarchy for new expressions to be proved. It keeps a list of subproblems generated by its use of detachment and chaining-proof methods on problem theorems, and then sets about solving these subproblems, which in turn generate more problems. This ". . . hierarchy is . . . not fixed in advance, but grows in response to the problem-solving process itself, and shows some of the flexibility and transferability that seem to characterize human higher mental processes [p. 162]."

Lindsay. Although mechanical translation of one language into another has proved to be exceedingly difficult (Bar-Hillel, 1964), some progress has been made in programming machines to answer questions. Lindsay (1963) used basic English statements about kinship relations as input for a program containing a model of the family tree. The computer was programmed to answer questions about kinship by inference from the model. Lindsay used the data from rather complex inferential processes to support his belief that accurate language models must attribute to the speaker (or computer) the ability to construct a usable representation of his (its) environment. A person uses sentences to refer to his environment and to construct an "internal picture" of his world. According to this view, questions are answered by the speaker referring to his "world view" rather than searching through a file of whole sentences stored in his memory.

Hayes and Clark. In a simulation study, Hayes and Clark (1970) investigated how people perceive language utterances as segmented into words. They specified three possible mechanisms that depend upon linguistic experience in order to

identify words: (a) a bracketing mechanism that identifies words due to their segmental markers, (b) a reference mechanism that identifies words by direct reference to objects, and (c) a clustering mechanism that detects recurrent patterns that equal words without the aid of pauses or meanings. The authors chose to demonstrate the existence of the clustering mechanism by composing an artificial language with no segmental markers, which was audibly delivered by a monotone computer voice. The language had a finite-state grammar with equal transitions between each word and another word or between each word and itself. In the first experiment, adult subjects listened to the computer language (consisting of only 4 words and 15 phonemes) for 45 minutes and then responded by indicating where they thought "pauses" should occur. Results showed a measurable tendency of Ss to recognize appropriate speech segmentation.

The authors interpreted this recognition process as follows: (a) at first the sound stream is amorphous and featureless; (b) after maybe one minute, some event (such as a phoneme) seems to stand out; (c) after this event occurs several times, Ss become aware of what usually precedes or follows it; (d) a combination of preceding and subsequent events can be related and labeled a "neighborhood"; and (e) finally, the authors presume that the correspondence works outward in each direction to form a kind of word boundary.

In their second experiment, the authors tested the uniqueness of the relation between the focal point and its "neighborhood." Acting on the assumption that in a language with fewer phonemes, segmentation would be more difficult, they programmed the computer for three languages, one using 16 phonemes and the other two using only 4 phonemes each. The results supported the hypothesis that difficulty of segmentation depends upon the number of phonemes in the language and not upon the information content of the words. The results also supported segmentation as a process which proceeds by relating a growing focus to neighboring events. The authors conclude that their experiments show that Ss have a clustering mechanism which is able to segment artificial speech. This mechanism (a) works on "speech" that has no semantic or significant syntactic structure, (b) can segment unutterable sounds, and (c) requires relatively little time to operate.

Although these two experiments used adult subjects, the conclusions could apply to the language-acquisition process in children. For during language learning, children cannot imitate exactly the speech they hear, but they can listen for correspondence and location of word boundaries in the successive speech stream. In addition, children have the benefit of intonation and inflexion in the natural language they hear.

The work of Hayes and Clark on the ability of human subjects to discern a form of language periodicity corresponds to Simon and Kotovsky's (1963) simulation program where conceptual problems were solved by developing a pattern description to generate the next member of a given series.

Feigenbaum. Developed by Feigenbaum and others (Feigenbaum, 1970), EPAM III (Elementary Perceiver and Memorizer) consists of information processes and structures for both learning and performance in paired-associate and serial verbal learning tasks.

> The job of the EPAM performance processes is to retrieve appropriate responses from the memory structures when the task so dictates. EPAM has two major learning processes: discrimination learning and stimulus familiarization. The former discovers differences between items being learned and those already learned, and builds up the memory structure to incorporate tests on these differences, so that storage and retrieval can take place with a minimum of stimulus generalization and confusion. The latter builds internal representation, called images, of verbal items being learned. It is an integrative process, in which previously familiarized parts of a stimulus item are first recognized and then "assembled" (according to a strategy) to form the internal representation. As previously mentioned, the EPAM model also contains a number of other mechanisms for attention focusing, organization of the learning task, associative recall. . . .
>
> EPAM, as it stands, is a psychological theory of certain elementary cognitive processes, framed at the so-called information-processing level. The primitives at this level are primitives concerning elementary symbol-manipulation processes. These primitives are not, at this stage of our knowledge, directly translatable into "neural language;" that is, statements about how the processes are realized in the underlying neural machinery. The EPAM theory generates complex and accurate predictions of verbal learning behavior [pp. 453-455].

Kelley. Kelley (1967) has based a computer program on a psychological model of language acquisition. According to his model, syntactic acquisition proceeds by a person (or program) processing sentences sequentially. Each sentence is understood if a correct analysis of the sentence is made. In the program a "parsing algorithm" models this process of understanding. This component takes a presented sentence and the grammar of the model, along with any current grammatical hypothesis which the model may have generated, and attempts to produce a syntactic analysis of the sentence. This analysis is a labeled bracketing of the input sentence along with an identification of the functional relations between sentence parts. The comparator component determines whether an analysis

of an input sentence is correct by determining whether it is consistent with what the child knows (based on his general knowledge of the world and his particular knowledge of the context in which the sentence was presented). If an analysis is inconsistent with what the child knows, it is discarded. If the sentence is understood, it joins the grammatical competence of the model.

When a sentence is correctly understood, the grammatical constructs used by the parsing algorithm to produce the analysis are confirmed, as are any grammatical hypotheses that were used. Also, the understood sentence may be a stimulus for the generation of a new hypothesis. Then the model receives another sentence to process.

The program includes both a time scale for presenting sequential sentences and a developmental time scale for acquisition stages. Each stage is characterized by the generation of a different set of grammatical hypotheses. During a particular stage the hypotheses are tested against the sentences presented and those hypotheses which are accurate characterizations of the language at that stage are confirmed while the others are discarded.

The principal mechanism for acquiring a grammatical construct is for a hypothesis to be sufficiently confirmed to become a part of the grammar. But word meanings are supposed to be acquired through the use of a word in one or more contexts. So the model's grammar may be changed directly by the incorporation of new words into the lexicon.

Kelley makes the following psychological claims for the parsing algorithm component of the model:

> 1. The process of understanding depends upon the grammatical competence of the child along with any hypothesis he may have about the language.
> 2. The child will attempt to account for as much of the sentence as possible in his analysis; and his analysis will be as habitual as possible in the sense that he will tend to use well-confirmed grammar constructs (both rules and categorical assignments) in preference to less well confirmed constructs.
> 3. The child is able to skip over parts of a sentence which are not understood and produce a structural description of the remainder of the sentence [p. 102].
>
> Hypotheses about lexical categories are used by the child to classify words that he might encounter in his verbal environment. The child is presumed to have the capacity to recognize whether a word . . . fits any of his hypothesized categories; when and if it does, that particular categorical assignment of the word is incrementally confirmed [p. 104].

The child also has hypotheses about the functional relations of words.

The different stages incorporated in the model are distinguished by the evolution of a new set of initial hypotheses for each. At stage 1 the child is assumed to possess a single holophrasic linguistic concept with the approximate meaning of "concrete reference." The child must also learn the meaning of words. This learning is credited to the experiencing of words in context. Words typically acquired first are content words, such as nouns, verbs, and adjectives (cf. Brown & Bellugi, 1964).

Stage 2 marks the beginning of syntactic development. Two categorical concepts appear as the model distinguishes between a class of "things" and a class of "actions."

> There is now an additional functional relation, called modifier of the sentence. There may in fact be several different types of modification subsumed under this label (possession, attribution, quantification, etc.) which in a more adequate model would be treated independently [p. 111].

At stage 3, the relation "subject of the sentence" is added to the two functional relations of stage 2.

> The model now has the new hypothesis that a sentence will consist of three parts: one part that functions as the "sentence subject," one part that functions as the "sentence modifier," and one part that functions as "sentence reference" [p. 122].

The stages are intended to reflect the psychological fact that the child will attempt to be as habitual as possible in the sense of using his previously acquired constructs in the analysis of presented sentences.

> In later stages the child will attempt to understand new sentences in terms of previously confirmed units, and when he does this by combining one or more of these units with one or more other elements, he will have a hierarchical analysis [p. 125].

Kelley concludes that:

1. Syntactic acquisition depends crucially upon the process of comprehension by the child; speech production is taken to be of secondary consequence at most.
2. The mechanism for syntactic acquisition is taken to be the testing of hypotheses about the language by reference to language data. These hypotheses are both initial (either innate or acquired extra-linguistically)

and contingent (derived from the language data themselves).

3. Semantics is taken to play a central role in syntactic acquisition. The differential response hypothesis (by which the mechanism for syntactic acquisition uses only "correctly understood" sentences) depends upon the child's interpretation of a sentence he has heard and his recognition of semantic anomaly, which in turn depend upon the semantic properties of both functional relationships and lexical categories.
4. The child need only be exposed to meaningful sentences from the language to acquire syntactic competence. In particular, language instruction (in the form of expansions, corrections, or ungrammatical utterances identified as such) is not essential [p. 148].

Quillian. Quillian (1969) has developed a program called Teachable Language Comprehender (TLC) which is capable of being taught to comprehend English text. When new text is entered into the program, it relates the text to a large memory network.

> The memory structure and comprehension process of TLC allow new factual assertions and capabilities for relating text to stored assertions to generalize automatically. Once such an assertion or capability is put into the system, it becomes available to help comprehend a great many other sentences in the future. Thus the addition of a single factual assertion or linguistic capability will often provide a large increment in TLC's effective knowledge of the world and in its over-all ability to comprehend text [p. 459].

Although TLC is still being developed and is limited by the length and complexity of input sentences, the author believes that its operations provide a theory of what text comprehension is and how it operates.

TLC's memory contains factual assertions about the world and "form tests" which provide the syntactic ability to relate a piece of text to memory. All factual information is encoded in memory as either "unit" (an object, event, idea, or assertion) or "property" (predication). Actual English words are stored in a separate dictionary with one or more "pointers" to units in the memory. The memory structure is a richly connected network of factual information about the world. Every unit or concept represented in the memory is directly associated with a set of factual assertions about the world and its properties, and is indirectly linked to an unlimited number of other "supersets" of units and the properties associated with them. "Pointers" to particular units in memory represent the meanings of natural-language words.

In the author's words:

> The theory of text comprehension is . . . difficult to summarize. Essentially, it asserts that to read text a comprehender searches his (her, its) memory, looking for properties which can be considered related to that text. This search begins simultaneously at all the representations of concepts, all the "candidate units," which the words of a given fragment of text point to. These will include units corresponding to all dictionary meanings of these words, and to any possible anaphoric referents these words may have. . . . TLC's search through memory is intended to locate in breadth, first, the order, and then intersections connecting properties in memory to words of the input text. Each such intersection that is found causes TLC to form a hypothesis about part of the intended meaning of the text. Specifically, this hypothesis is that the text means to imply a relationship . . . between particular words of the text. These words are: the "source" word--that which supplied the initial candidate leading to this property: and the "identified" word --that which has been found to have an intersection with this property [pp. 474-475].

The above hypothesis is generated on the basis of semantic relationships and requires syntactic testing before it is confirmed. If the syntactic relationships are compatible, the memory property is said to be related to the text. This property is then taken as a model to be recopied and the copy is adapted to encode a part of the text's meaning into memory. By using adapted copies of these properties, the comprehension procedure creates a complex, intralinked structure representing the meaning of the input string.

The theory above relies on the idea of comprehension being based upon the comprehender's "knowledge of the world." TLC is designed to carry out extensive memory searching with little wasted effort. "This kind of 'semantic' processing controls the entire comprehension process, with syntactic analysis used in the service of deciphering meaning, rather than, as is often suggested, the reverse [p. 475]."

> The argument for TLC as an efficiently "teachable" computer program rests on the fact that both the program's knowledge of the world and its ability to perceive syntactic relationships are fragmented, so that they can be built up in a machine piece by piece. The memory structure allows automatic generalization of each such piece added to this memory, since TLC will recognize a given property's relationship to text despite considerable variation in the form of that text . . . [p. 475].

<u>Simmons and Burger</u>. After reviewing the literature on national-language computer processing, Simmons and Burger

(1969) find that syntactic analysis by computer is fairly well understood while semantic analysis is still in the preliminary stages of formulation. They conclude that no general language processor will be developed until the notion of "meaning" and the way it is communicated by humans through language strings is understood. As a basis for understanding language, a cognitive model must represent verbal events, syntactic relations among them, and their mapping onto the cognitive events they stand for.

In their system, the syntactic and semantic analyses are not separate nor is one considered primary over the other (as opposed to Katz). The system operates directly on elements of an English sentence string to transform it into an underlying relational structure. The programming procedure operates in agreement with linguistic theories formulated by Chomsky and others. The underlying assumption "is that semantic characterization of a word is a matter of relating it to classes of meanings in which it partakes [p. 5]." A sentence processed by the program is transformed into several syntactic structures (Sentences that are too complex cannot be processed successfully). The aim of the program is to derive from a given English sentence string a set of deep base structures to represent each of its possible meanings. The authors conclude that a semantic analysis system is remarkably similar to a syntactic analysis system. As a result of this work, they hypothesize that

> deep underlying structures of sentences with unique identification of word sense in context can be obtained with considerably less mechanism than most previous experience with transformational theory and recognition systems would lead one to believe [p. 13].

Schwarcz. Schwarcz (1967) views the linguists' assumption of an ideal speaker as a fundamental error. He proposes a performance model which takes into account: (a) individual differences in competence and changes in a single speaker's competence over time; (b) the ease and efficiency with which the model can be employed in generation, parsing, and modification; and (c) the primacy of semantics, including the speaker's knowledge of the world, represented in a kind of conceptual network in the production and understanding of utterances. In trying to account for these considerations and to form a theory of linguistic performance, Schwarcz states the limitations of a computer model as being: (a) the use of finite strings made up of a discrete and limited set of machine-usable characters instead of continuous streams of input, and (b) the use of letters of the alphabet instead of auditory output. He suggests that instead of using "deep structures" and phrase-structure grammar with complex rules, a theory should start with conceptual structures extracted from a conceptual network that expresses a speaker's present

knowledge of the world. Then transformational rules could operate on this conceptual structure to produce a surface structure that is lexically and phonetically interpreted to produce an output form of the sentence.

Schwarcz bases his preliminary model on these assumptions: (a) information about language is represented and processed in the brain in the same way as perceptual and conceptual information about the world to which language refers, and (b) linguistic and conceptual representation and processes are the same in a performance model as in a competence model. The advantage of these assumptions is that semantic information can be used in syntactic processing, and vice versa, thus eliminating the boundary between syntax and semantics drawn by most linguists. By the use of simple entities (such as individuals, classes, relations and operators), operators in the model can be paradigmatic and syntactic, and both conceptual and syntactic information can be represented in the same way. These rules will enable a computer to analyze and synthesize structures that are both conceptual and syntactic.

Schwarcz outlines the logical (not necessarily developmental) order of steps in language learning as: (a) discrimination and use of clustering, (b) referential association, (c) learning co-occurrences and linear ordering of relations among lexical items, (d) the development of functions as a result of generalization of similar co-occurrences into classes and resulting rule formulation, and (e) the transformational learning phase (or the learning of equivalent modes of expression for the same or equivalent semantic concepts which may be related to each other through structural transformations).

This proposed performance model implies a reshaping of linguistic theory because of its elimination of traditional distinctions like syntactic-semantic with respect to the knowledge of the speaker and their reestablishment with respect to the different phases of processing employed by the speaker. The author believes that an emphasis on performance models in linguistics will lead to a merging of linguistic and psychological theory.

Trabasso et al. Trabasso, Rollins, and Shaughnessy (1970) have developed a model of how people process positive and negative information. The model concerns the processes of matching, recognizing, evaluating, comparing, or comprehending any two successive inputs of information. These inputs can be objects, pictures, single words, or complete sentences. After the inputs are compared, the subject reaches a decision and responds. The two basic operations involved are: (a) coding the materials so that they can be compared, and (b) matching the coded representations. Throughout the process, the person tries to represent the information in the

affirmative. According to the authors, this is accurate because "positive representation allows direct search-and-compare operations on features and events in the real world [p. 66]." Transformation of negative information is required during processing. The coding and matching operations are serial. The basis of the model is a general coding operator and matching operator (COMO).

> The subject begins by coding the features of the first input. Negative inputs are represented by features plus a negative indicator. If the values are binary, the subject may transform into the affirmative complement. Then he codes the second input so that its features may be matched against those of the first input. The subject is set to match identical codes so that responses such as TRUE or SAME are primed. If a mismatch occurs, he engages in another activity such as rechecking features and resetting his response to FALSE or DIFFERENT. Then a final check or negation is made. If one negation is present, the response dictated by the matching outcome is changed. If both codes are affirmative or negated, then no response change is made [p. 67].

According to the authors, the statements above are similar to an encoding-comparing model developed by Chase and Clark (1970).

Research Literature on Information Processing Models

Miller's chunking hypothesis has proved valuable in stimulating research. For example, Epstein (1967) tested the effects of syntax on learning by using a factorial design including structure, syntactical sample, "chunking," and learning instructions. One of his objectives was to test the "chunking" hypothesis as an account of the facilitation produced by syntax. He found that "chunking" did interact both with the structure and the instruction variables but not in a way that supported the "chunking" hypothesis.

Putting this kind of information-processing theory to work, Miller and Selfridge (1950) investigated sequential probabilities in a learning task involving word strings of varying degrees of likeness to typical English word order. Their tests suggested that sequential dependencies rather than meaning enhance correct recall. "If the nonsense [of remoter approximations] preserves the short-range associations of the English language that are so familiar to us, the nonsense is easy to learn."

Miller also investigated the recall of structured (therefore redundant) strings of letters in contrast to random

strings. Results showed that the redundant strings are learned faster but a decreasing amount of information is conveyed as the redundancy increases.

To test the depth hypothesis, Yngve conducted an experiment showing that sentences with left-branching and with multiple-branching structures tend to have greater depth measures than right-branching structures. Miller and Chomsky (1963), however, found that left-branching constructions do not seem more difficult for hearers than right-branching constructions, and that multiple-branching constructions seem easiest of all. Although some experimental findings support their views, it may be argued that Yngve's hypothesis is applicable to speakers whereas hearers do not appear to have the same degree of difficulty with depth. However, Miller indicates that subsequent research on this program is inconclusive (Chomsky & Miller, 1963).

Recursive embedding in sentences was also tested by Chomsky and by Miller. Chomsky proved that any language that does not use recursive embedding (particularly self-embedding) contains sentences that humans or programmed subjects with finite memories cannot understand. For the subject must remember to relate each left portion to its corresponding right portion and if the subject's memory is limited, some sentences will be impossible to process; e.g., "remarkable is the rapidity of the motion of the wing of the hummingbird," transferred to self-embedded form becomes "the rapidity that the motion that the wing that the hummingbird has has has is remarkable."

Miller (1967) presented subjects with the task of memorizing completely grammatical sentences with four embeddings. A sentence with no embeddings read: "She thanked the producer who discovered the novel that became the script that made the movie that was applauded by the critics." A sentence with four embeddings read: "The movie (that the script (that the novel (that the producer (whom she thanked) discovered) became) made) was applauded by the critics [p. 114]." In the experiment every version of the sentence contained the same 22 words. When the order of these words was rearranged, the subject's cognitive operations had to be rearranged. The results of the experiment showed that all subjects could perform with one embedded clause, some could perform with two, but all had difficulty with three or more embeddings, showing how limited our recursive abilities are.

Mandler's (1967) experimental paradigms in the study of clustering or the role of hierarchies in memory are relevant to computer models of simulation. But these paradigms have not been applied in conjunction with highly specified models. There has been little empirical work relating detailed predictions from computer-simulation models to laboratory data on human performance.

Reitman (1970) observes that Simon and Kotovsky are describing "a concept-induction and sequence-extrapolation model in which the alphabet is represented as a linear string." In every case, it is assumed that this string is entered at the beginning. An experiment by Sanders (1965)

> suggests that this set of process and structure assumptions is inadequate. Instead, his data are consistent with a conception of the alphabet as a random-access string. The time subjects need to respond with a letter some fixed distance from a stimulus letter varies . . . not with the position of the stimulus letter in the alphabet [p. 485].

There is further evidence against the sequentially processed linear-string assumption.

Trabasso, Rollins, and Shaughnessy (1970) have conducted research studies to test the existence of different stages of processing of simple lexical units, as posited in the COMO model. In one experiment, subjects were asked whether or not a hypothesis in the form of a single adjective was true when compared to a real referent. The results showed that subjects had a set to match identical representations of events. Their decision rule was based upon whether the second input matched the coded representation of the first input.

Trabasso cites another experiment designed to test Chomsky's (1957) theory of transformational grammar, in which sentences served as descriptions. Pictures of events were the objective referents. Both these experiments and other work by Slobin (1966c) confirmed the COMO model when the sentence is presented before the picture to be matched. Slobin's data indicated that children wait until they see the pictures before they begin processing, whereas adults begin processing as soon as they hear the sentences.

Overall, the model and tests indicate that negative information is more difficult because it requires more operations in order to be understood. Trabasso and his co-authors (1970) believe that the model "provides an analysis of what is meant by comprehension in processing utterances against referents as well as hypothesis testing in inductive reasoning [p. 76]."

Critique of Information-Processing Models

Miller and Chomsky (1963) criticize finite stochastic theories of communication (which draw upon information-processing theory) because human subjects are capable of producing an infinite number of novel sentences and because stochastic

theories cannot account logically for children's language acquisition. They state that a complex theory is necessary to explain how simultaneous complexities of thought change into a segmented flow of language. It is difficult to construct a transformational system that is both empirically accurate and subject to abstract study. One problem with the Kelley model, for example, is that it is incomplete because language acquisition is multifaceted rather than sequentially categorical. Moreover, the use of three stages oversimplifies a process that probably is made up of more than three. The model does not explain the evolution of a mechanism for characterizing functional relationships in terms of deep-structure phrase markers. Another criticism that may be made of Kelley's model is that there is no direct signal for disconfirming a sentence. This absence of confirmation causes the information to degrade and finally to be dropped from memory. In one experiment where nonsentences were presented, the acquisition was not affected by the presentation of nonsentences. The model did not interpret the ungrammatical sentences because there were no hypotheses for which these nonsentences were relevant models.

Kelley thus confronts the problem of supplying direct proof of his work, particularly the differential response hypothesis. His answer is that the main evidence is indirect and that it consists of showing that, with certain assumptions and approximations, early syntactic acquisition can be explained. Kelley considers the use of formal models for the development and testing of theories to be the most productive method of inquiry at this time. He sees the purely linguistic study of grammatical universals in natural language as likely to be of the most consequence for theories of language acquisition.

In 1968, after two years of development, TLC was still workable only on simple, isolated phrases and sentences, and lacked the "ability to recognize that many input phrases refer to memory information stored as other, not directly mentioned concepts." For example, "male child" should evoke the comprehender's knowledge of the concept "boy," and "old man" should evoke his knowledge of the concept "old-man," even though in English this concept has no single word name (Quillian, 1969, p. 473). TLC also lacks the ability to reason spatially or to generate visual-like imagery as people do. Also, the program cannot store its encoded output back into memory without the aid of a human monitor. Finally, TLC's memory retains specific information unnecessarily; that is, such bits should be generalized or forgotten if it is to reproduce what human comprehenders do.

Yet, viewed as a theory of language comprehension, much of TLC's strategy is independent of the kind of mechanism that illustrates it. As Quillian says, this mechanism could

be viewed as a computer program, a person's brain, or whatever else could perform it. He regards it as a psychological theory and cites reaction-time data supporting the idea that human semantic memories have "at least an overall organization like that of TLC [p. 459]."

Reitman (1970), however, has seriously questioned the correspondence between information processing models and biological or psychological reality.

> . . . if the functional organization of the human information-processing system roughly parallels that of a digital computer, with its passive repositories of information and its one or two serial processors mediating all activity, then the great unsolved problem is how, out of the local changes in our billions of neurons, that form of organization is achieved. If current programs fall short in the ways we described, it may be because almost without exception they embed strategy systems inferred from human behavior in functional organizations very different from those the biological evidence suggests mediate such behaviors in man. The corollary is that it is alternative forms of functional organization we ought to be investigating in our programs. . . . The problem is . . . the inadequacy of our concepts of functional organization [p. 498].

The problems encountered in comparing machine models of memory and humans are due to organizational procedures in the programs. In the unsolved problem of language translation, it seems to be a question of semantics; the human knows and can use more information than programmers are able to organize in their computer programs. There is a choice involved. We assume that memory is a passive storehouse of information, waiting to be operated on by retrieval processes or search designs. Or we can assume that human memory is an active process, as Hebb (1949) suggests. The latter alternative increases the difficulties immensely.

Computers are still limited by storage (memory) capacity, speed of access, and retrieval systems although improvements are constantly being sought. Also, simulation programs cannot, as yet, sufficiently take account of differences between computers and people. For example, (a) people often get bored during experiments and problem-solving behavior, (b) people often fail to remember information whereas computers have perfect memories, and (c) people have conflicting emotions and motivations whereas computers do not. In the future, some of these differences may be accounted for, such as programming a less-perfect memory, which would more closely resemble human capability.

The most positive aspect of information-processing models is that psychological assumptions can be empirically

tested in computer programs that are detailed and rigorously specified. Computer programs of these models can be as complex as necessary to account for the variables, parameters, and their interrelations. Such complexity makes it possible for information-processing models to combine memory with the study of language because the models and programs can be structured hierarchically.

Finally, information-processing theories provide a psychological account of behavior, showing that there is a range of explanations for human behavior (neurophysiological, biological, etc.) and that none of them is exclusively correct or more basic than any other.

IMPLICATIONS FOR READING

Introduction

The models of language acquisition which have been delineated in this paper attempt to describe and explain the processes by which the babbling of the infant (which is the same in every language) is transformed into the natural language spoken by adults around him. They are concerned with the question of how the child learns to understand and speak his first language. Since the major part of this transformation is accomplished before the child makes his first acquaintance with the printed word, the models have little or nothing to say about reading. This fact may be interpreted to mean that they are irrelevant to reading.

Before attempting to answer this question, it is necessary to make two points. The first point is made by Smith (1971) in the preface to his recent book, Understanding Reading:

> The reading process and reading instruction are two quite independent domains of inquiry. Workers in each area should influence each other, perhaps much more than they do, but only by sharing information and stimulating hypotheses; they cannot pass judgment on each other's methods. A theory is useful as a summary and framework for what is known, and as a source of new ideas; a theory is tested by data acquired under rigorously controlled conditions. Instructional techniques, on the other hand, are of value only if they are proved to be effective in the classroom by the achievement of instructional and other educational objectives [p. viii].

A review of models such as this one is a theoretical enterprise designed to further the understanding of the reading process. It is not intended as a contribution to the "great debate" on the relative merits of various instructional

techniques. In fact, the premise on which the literature search of the Right-to-Read Program is based has been well summarized in Smith's opening statements:

> The current instructional methods are probably not much inferior to the methods we shall develop as we learn more about learning to read. So many instructional methods have been tried, and so many succeed (in some instances at least), that further permutations in the game of instructional roulette are unlikely to produce any great gain, either by chance or design. What will make a difference is an understanding of the reading process [p. vii].

No attempt will be made in this section, therefore, to prescribe methods or techniques for reading teachers. The fact is that reading is a very complex phenomenon, and we need more understanding of all the elements--perceptual, cognitive, affective, linguistic, and others--before we can begin to "bridge the gap" between theory and instructional practice.

The second point which emerges from the first is that, given this complexity, the goal of constructing a single model of the reading process which can take cognizance of all the above factors is far from being accomplished. As we have seen from a survey of language models alone, there is at the present time not even a semblance of convergence on the part of model builders in this area. The whole area is itself relatively new and bursting with activity. New material appears almost weekly; questions are heatedly debated and fresh insights are brought to old data. Language models are in a state of "becoming"; they are incomplete and subject to momentary change. Given this state of affairs, it would be premature and inappropriate to attempt an integration of models within this area, much less a merging of one or more linguistic models with models of the reading process itself.

It does not follow, however, that linguistic models are irrelevant to reading. Some authors have argued that no useful information about the latter is to be gained from a study of the former. These authors are at pains to point out that writing is not simply speech in print; that writing is a concise, formalized abstract mode of expression, while speech is redundant, colloquial, fragmentary (anyone who has typed the proceedings of a conference from tape can attest to the editing necessary to remove these irrelevancies). Moreover, it is argued, language is acquired naturally, without formal instruction, and its acquisition is completed in the short space of two years, while reading is formalized, takes a long time, and is often the focus of great anxiety on the part of children and parents alike. Other writers (e.g., Weaver & Kingston, 1971) see language development as prolonged, while the acquisition of reading language is

telescoped over a period of three years of the primary grades. Presumably, the conflict here is in the meaning assigned to "language development." The linguists are talking about the acquisition of syntax, while the reading specialists are referring to vocabulary development and the ability to handle more complicated structures.

Since the models described in earlier sections will certainly have very different, even contradictory, implications for reading, each group will be considered in turn.

Developmental Models

Behaviorist Models

In spite of the linguists' devastating attacks, many behaviorists remain convinced that no new principles are required beyond those invoked to explain other kinds of learning. One implication of this position is that there is no "critical period" which is better for language learning and beyond which little language development occurs. On the contrary, the teacher may analyze and build on the child's existing skills at any point in time by systematic substitution or reinforcement of sequenced stimuli calculated to assist the child in learning new generalizations, discriminations, and mediating responses. Certainly, operant conditioning techniques have been shown to work when applied to teaching children with few or no verbal skills. Staats (1964) points out, though, that learning to read is much more intensive and more likely to be attended by failure and punishment than the acquisition of speech. He recommends that learning to read be made a more gradual process, perhaps starting earlier and extending by small steps further into the primary grades. Also the reinforcements involved in learning to read may be much less potent than those involved in language and we need to discover more effective rewards to apply to the learning-to-read process. What kind of reinforcements are effective seems to be still open to question and to depend on the individual's past history. Staats (1964) found that extrinsic rewards (tokens, candy) were necessary to persuade three-year-olds to participate in his reading programs, but Harlow (1965) concluded from his studies of curiosity that intrinsic rewards are more effective for school learning. Bloom (1971) suggests that extrinsic reinforcement should be used consistently in the early stages of learning to read, and be replaced by intermittent reinforcement at longer and longer intervals until reading acquires intrinsic reward value. In any case, the teacher still needs to be aware of the individual differences in the reinforcement histories of the students.

The controlling stimuli, i.e., reading material, may also be manipulated to evoke the proper responses. The order

of material presented should be from simplest to most complex, presumably starting with the discrimination of individual letters and progressing to words, phrases, and sentences. Under this system it is necessary for the teacher to have not only precise behavioral goals but also a complete knowledge of the child's skills when he starts the reading program. Carroll (1970) points out that the child must know the language he is going to read and must learn to reason and think about what he reads. The language requirement implies that the child who does not have a fluent grasp of the language to be used in the reading program must either be taught that language or the reading materials that he uses must be put into his own language (or dialect). The reasoning requirement suggests the need to have children understand that written material conveys information which is to be processed and acted upon, just as does the speech flow to which he is accustomed to responding. Since activity on the part of the learner is a built-in feature of programmed learning, it should be easy to incorporate this requirement into materials based on operant conditioning methods. In fact, these methods have been used mostly with very slow readers, and seem to be more successful in eliciting already learned responses than in teaching reading skills (Staats, 1964).

In summary, it may be said that the behaviorist models of language acquisition have not as yet met the challenge posed by linguists, in spite of MacCorquodale's (1969, 1970) spirited defense of the Skinnerian position. However, the methods have potential application to reading, provided that the goals are clearly specified, the materials meaningful, and the child's reasoning powers challenged by these materials.

Nativist Models

As noted, Lenneberg's model places heavy emphasis on a critical period for language learning, primarily between the ages of eight months and four years. If we accept the statements of a number of authors (Carroll, 1970; Downing, 1969; Gibson, 1970; Kagan, 1970; Lawton, 1968; Zedler, 1970), there is a direct relationship between a child's language and his acquisition of reading skills. The nativistic thesis clearly implies that early intervention programs involving language are of critical importance for children who do not receive adequate language training in the home. The models do not prescribe the particular kind of language intervention, though one could infer that the most desirable would be one which closely approximates the natural-language learning environment of the home. Programs that artificially induce language, such as the Bereiter-Engelmann approach, have been criticized for failing to encourage spontaneous verbalization. Moskovitz (1968), for example, complains that this is a simplistic approach to a complex problem, since it fails to

conceive language as a communication process or to consider the relationship between language and thought.

Recently, several authors have expressed the view that there is no such phenomenon as a "nonverbal child." A child may appear nonverbal even though he has a well-developed language system because he is unfamiliar with the vocabulary and grammar to which he is exposed in school. But standard English is not a completely foreign language to a dialect-speaking child. There is some overlap in vocabulary and syntax structures (as well as features of the linguistic universals) on which the child can construct a knowledge of standard English, if he meets it in meaningful situations, and is given time to assimilate it into his own structures. Blank's project (Blank & Solomon, 1968, 1969) used language to solve cognitive tasks.

Currently, our language-intervention programs are not reaching children during the "critical period" of language acquisition, but seem to begin at age four, about the time the maximum growth period ends. Scott (1962), who has been one of the primary advocates for the critical-period concept, finds that the same experiences, which are essential during the growth period, may have different consequences or no consequences before and after the critical period.

Cognitive Models

Piaget's theory suggests that abstract symbols are meaningless to children unless they have a firm grounding in concrete experience. Experiencing objects and events and coming to appreciate their many dimensions and ramifications is a slow process, and it is especially slow if we think of names or labels as referring to classes, rather than single objects, as Brown suggests. Young children have fragmentary and imprecise concepts. Their reasoning abilities develop gradually because, according to Piaget, new experiences cannot be fully assimilated until they have the requisite structures. This would suggest that reading in the sense of learning phoneme-grapheme correspondences might profitably be delayed until at least the beginning of the concrete operations period (7-11). This does not mean that the child is not learning prior to the beginnings of formal instruction. On the contrary, if he is given a good environment with opportunities to grow, he is laying the foundation for a true understanding of the purpose and meaning behind the mechanical act of reading. Furth (1970b) has used Piaget's theory to launch an attack on the school's obsession with reading to the exclusion of what he sees as its primary function, teaching children to think. Educators have placed such emphasis on reading ("because everything else depends on it") that they have deluded themselves and the public into thinking that teaching reading is the primary mission of the schools. Actually, it is an

abstract way of representing experience and of communicating it to others. The implication is that, if children are provided experiences which challenge their thinking, learning to read need not be the tedious, anxiety-ridden process it often is, but can be introduced gradually and naturally, as a tool to aid thinking and communication. In this respect, there is certainly a parallel between learning language and learning to read. Some schools have used an integrated-day approach which attempts to embody these principles, and report that both reading and writing can be successfully taught using these methods.

Krech (1969) has addressed himself to the problem of the precise nature of the "enriched environment" that should be provided for young children in order to promote thinking. His major concern was with the biochemical transformations occurring in short- and long-term memory. In one experiment, rats that had lived for 80 days in an environment enriched in every possible physical and social way were found to have larger brain cells, a better blood supply, more glia cells, heavier and thicker cortex, and greater activity of two brain enzymes than their deprived counterparts. Krech then devised a series of experiments to determine which of the many amenities were the most significant and concluded that the only experience that was really effective was the freedom to roam around in a large object-filled space which presented continuous and varied maze-producing problems.

Krech concludes that the type of stimulation that is most effective in developing the brain is what he calls "species-specific enrichment experiences." The effective rat brain is one that is a good "space brain." What then are the species-specific enrichments that will develop the human child's brain? Krech suggests that language is probably the clearest instance of a pure species-specific behavior, for it is only in the human brain that "_speech and language clearly depend upon certain areas in the neocortex_, areas for which there simply are not analogues in the brain of any other animal [p. 8, author's italics]." For this reason, he urges the educator to turn to the psycholinguist, as well as the proponents of the "cognitive" or "productive-thinking" approach, for major guidance in designing a rational educational enrichment program. In other words, what is good for early childhood education is, in this case, good for reading instruction. For reading is a cognitive activity, a search for information and meaning; and a child who has a well-developed, active brain and is curious about many things is the one who will perceive reading as a tool to further his own goals of acquiring and communicating information. We can lay the groundwork for this perception by developing language competency along with cognitive competency. It is a question of how we may most profitably have children spend their early years. By repetition and programming, we may be able to

induce recognition of printed symbols, giving a semblance of "reading." But, until the child understands the meaning of what he reads, this is empty verbalization. The best learning at this age comes through experience, not through abstract symbols.

Psycholinguistic Models

Phonological Models

Jakobson's (1968) model suggests that there is a natural order for the emergence of sounds and that this order is universally found in all languages of the world. McNeill has further suggested that the most difficult phonemes are also the rarest, or in some languages, nonexistent. No such correspondence exists between the frequency with which words occur (in English, at least) and their difficulty. Common words such as the, there, their, here, etc., pose difficult problems of discrimination for some children.

If we accept the principle that reading materials should be based on language with which the child is familiar, it might be helpful for authors of beginning readers to examine the phonemic constituency of the speech used by the population of children for which the materials are intended. In this way, difficult or nonexistent phonemes occurring in the dialect may be postponed.

Syntactic Models

The major advantage of syntactic models is the introduction of the concepts of surface and deep structure. Although some authors find the distinction unnecessary, it has the virtue of having stimulated new models not only of language but also of reading and of having generated a wealth of research in both areas. In the study of reading, the concept of deep structure has given rise to an increased and welcome emphasis on the process of reading for meaning. Smith (1971) points out that "reading for meaning" entails making use of information simultaneously at both the surface- and deep-structure levels of language, using elements of both visual and semantic information. He makes a distinction between "mediated meaning identification," which is the "lower-route" to comprehension through the identification of individual words, and "immediate meaning" which goes directly from graphic feature discrimination to meaning identification. Fluent readers utilize the latter process. They use rewrite rules to transform the surface structure of the printed passage into their own deep structure, and to assimilate it into what has gone before in the passage and into previously accumulated experience. The actual words used are not retained

in long-term memory (unless they are very striking, or need to be retained for some particular purpose), but the meaning is. Reading methods which emphasize word and letter identification to the exclusion of reading for meaning are missing the point, which is that the fluent reader learns to read with a minimum of visual information from which he reconstructs meaning.

At the lower grades, teachers frequently place great emphasis on oral reading. Smith (1971) believes that this practice, too, reflects a common fallacy.

> There is another widespread misconception that spoken words have a kind of magical character; that their meaning is apparent the moment they are uttered. Therefore, all one has to do to acquire the meaning of written words is to convert them into vocal or subvocal speech. But spoken words in their physical manifestation are just as far removed from meaning as the marks on a printed page. Meaning is not in the surface structure of language, either spoken or written; meaning in each case has to be constructed by exactly the same grammatical and semantic processes. "Converting" a written message into verbal form does not itself provide the meaning; it merely interposes an additional stage in the process of comprehension [p. 207].

The processes by which immediate meaning identification is accomplished are not fully understood, but two related points may be made. First, it is noticeable that even fluent readers resort to mediated meaning identification when the material being read is unfamiliar, difficult, or ungrammatical; i.e., they identify and repeat individual words, sometimes aloud, in an effort to reconstruct their meaning. This is what a poor reader is doing all the time, either because the material is too difficult, or because he does not have the background of experience to make the communication meaningful. Second, like any activity, reading becomes proficient with practice.

> Learning to read is akin to any other skill; there are perhaps some specialized exercises that one can undertake to iron out particular difficulties, but there is no substitute for engaging in the activity itself. Reading involves looking for significant differences in the visual configuration to eliminate alternatives, and knowledge can be acquired of what differences are significant only through experience. This knowledge cannot be taught. It has to be acquired; the major contributions that the teacher can make are to provide information, feedback, and encouragement [Smith, 1971, p. 209].

Chomsky's model, it may be remembered, separates meaning from grammar because a sentence such as "Colorless ideas sleep furiously" is meaningless, though grammatical. Still,

there is a sense in which the above sentence is more meaningful than "Sleep colorless furiously ideas"; i.e., the scale of grammaticalness is correlated with the scale of meaningfulness, even though these two aspects may be studied separately. The child whose language has a different grammatical structure will experience difficulty in extracting meaning from the unfamiliar structures of written prose unless he has previously experienced some approximation to those structures in the speech of adults around him. Granted that written sentences are structured differently from the same ideas conveyed in speech, there are also many points of similarity and convergence between the speech heard in middle-class homes and the reading materials encountered in the school. The middle-class child is able to capitalize on these similarities so as to anticipate the format and content of sentences in print. The child from a home where only a dialect is spoken needs the experience of hearing standard English like that spoken in middle-class homes for a year or two before he learns to read. Given Chomsky's distinction between competence and performance, it would appear to be unnecessary that the child should use these structures in his own speech, but he should have experience in hearing and interpreting speech cast in this mold. None of this implies that dialect-speaking children should be made to feel inferior about their language by having their speech and grammar corrected. The implication is that they should be led to an appreciation of the fact that standard English is the foremost means of written communication not only in this country but in many other parts of the globe.

Semantic Models

Psycholinguistic models which deal with the semantic aspects of reading tend to place emphasis on the reader's use of contextual clues to derive meaning from the printed word. Goodman (1970) has described reading as a "psycholinguistic guessing game," in which the reader uses his knowledge of the grammatical constraints of the language and his familiarity with the meanings of words and the frequencies of their occurrence in particular groupings to reduce the probable alternatives of what follows next in the passage. Again, this implies that the reader must have experience not only with word patterns, phrases, idiomatic expressions, etc., in print, but must have encountered these and similar expressions in everyday life, so that he can attach the meaning of the printed word to concrete experience. Poor readers frequently stumble over such expressions as "once upon a time" which should trigger immediate meaning. Goodman analyzed the errors made by a proficient fourth-grade reader attacking a story which was (intentionally) slightly difficult for him. The child's errors could, in most cases, be termed "reasonable." For example, he read "might as well study word meanings" as "might as well study what it means." Goodman points

out that not all deviations must be treated as errors, in the sense that the child is regarded as not knowing something, or as being "careless." In fact, children should be encouraged to form reasonable hypotheses based on structure and content and to use visual cues to test the accuracy of these hypotheses. If the child has learned to read for meaning, the passage itself will provide corrective feedback, because errors in reading single words will change the meaning of the sentence so that it no longer fits the rest of the passage or, more likely, will render the sentence completely meaningless. By the same token, a child for whom reading consists of word identification will proceed happily misreading key words without realizing that what he is reading is nonsense.

One possibility is that children may learn about the constraints of language through word games that involve using cues and meanings to enumerate alternatives and to predict those which are most likely from the context. For example, a group of children might start with a simple word group like "the boy ____ the ball" drawn from a passage. The possibilities for filling the blank are: has, holds, throws, etc., or threw, hit, lost, took, bought, etc. (perhaps in descending order of probability). The children would be asked to suggest words to fill the blank and would discuss the probabilities inherent in the grammatical structure and in the meanings of the given words. They might then search the preceding and following sentences in the passage for clues. The first clue to look for could be whether the rest of the passage is written in the present or past tense. A decision on this point would eliminate 50 percent of the alternatives immediately. The children would continue to reduce the number of alternatives in this way until they were able to determine the correct word. This technique could be used at different ages and with materials of increasing difficulty or ambiguity.

Again, the success of this, and similar methods, presupposes that the child has had experience so that he can generate the most plausible hypotheses. In the simple example provided, he must know that one hits or throws a ball, but does not ride or eat it. This aspect of reading is fully as important as letter and word identification, but it receives much less recognition.

Ruddell's (1970) model elaborates on the complexity of the reading process, which is too often forgotten and ignored. Like Goodman, Ruddell places primary importance on denotative and connotative meaning, as well as on "non-linguistic meaning," transformational and rewrite rules, and feedback mechanisms for evaluating running discourse. In addition, he observes the influence on these mechanisms of cognitive strategies which the individual has acquired for identifying written symbols and for translating them into his own meaning system. Ruddell is one of the few model

builders who recognize the role of affective factors in spite of a body of research literature that shows the effects of these factors on comprehension.

Information-Processing Models

Information-processing models have been instrumental in providing several basic concepts that have proved useful in the study of reading. In addition to the notion of "bits" and "chunking" of information, is the concept of redundancy, which may be applied to both spoken and written material. Redundancy is closely bound up with the reduction of alternatives, making it possible to study not only the amount of redundancy needed to reduce the alternatives to manageable proportions but also the differences of redundancy which occur in speech and writing and the implications of these differences for beginning reading.

There is more information in the speech stream than the listener uses to comprehend the speaker's message. Likewise, Goodman maintains that there is more information in the visual stimuli than the fluent reader uses to process written material. Information-processing models suggest that, in both cases, the listener or reader imposes patterns on the stream of "noise" passing before his senses in an attempt to impose meaning on what he hears and sees. Even nonsense streams are perceived as segmented according to syntactic rules. This suggests that children should be encouraged to look for semantic and syntactic patterns in reading material and to recognize that such patterns vary with the type of material and the style of the author.

Feedback is also a central concept of information theory with profound implications for reading. A proficient reader uses many kinds of feedback (visual, auditory, syntactic, semantic, etc.) to check the accuracy of the decoding and comprehension processes. Many of these kinds of feedback involve skills that the child can learn, and should be encouraged to learn.

Most computer programs that simulate human language processes emphasize the importance of a "dictionary list" or vocabulary storage in memory. This implies that the child needs a rich vocabulary of spoken and written words available for matching with new stimuli. While there is some merit in learning vocabulary lists in which words with the same phonetic components are grouped together, there are other occasions in which the phonetic attributes may be a distraction. Chomsky (1970) suggests that the underlying meaning is a more significant aspect than phonetic form, e.g., nation-nationality, nature-natural, etc., are word pairs which, though phonetically different, are recognized by speakers of the language

as variants based on the same root words. Enrichment of the child's vocabulary may be brought about by building such word families, enabling the child to progress directly to the meaning of what he reads. Finally, it is possible that pupils could learn a great deal about language by writing simple programs for the computer, which generate sentences, paragraphs, and even poetry or short stories (Time, 1971).

Needed Research

While there are a number of models of the language-acquisition process, there is no single model, psychological or linguistic, which is completely adequate to explain the many aspects of this complex process. Much refinement of the models and much research are needed before any one of the models can approximate a satisfactory explanation of language development. On the other hand, none of the models included could be dismissed, since all were able to meet the criteria of a useful model in some degree, and each one commands a following among psychologists or linguists. Any attempt to integrate the models would be inappropriate and premature at this time; rather, efforts should be directed toward expansion, elaboration, and testing of the individual models.

At this point in time, behavioristic models of language have suffered a setback from which they have not, as yet, rallied. Chomsky's attack on Skinner's operant account of language was an important milestone in showing the severe limitations of learning theory in describing language. However, in the slightly more than a decade that has elapsed since Chomsky's attack, some psychologists with behaviorist leanings have continued their work on both the theoretical and the practical front, using the principles enunciated by Skinner. Their results, and the successful practical application of operant conditioning techniques, suggest that learning principles have validity for at least some aspects of language learning. Research is needed to determine the precise ways in which concepts taken from learning theory apply in the area of language. More specifically, reinforcement has been found to be most effective with children with learning disabilities or speech deficiencies. While this work might with advantage be extended to other types of learning problems, more research is needed on other groups (normal and bright children). A plausible explanation is also needed to account for the superiority of such methods with language-deficient groups.

In fact, we need to know with much more accuracy what kind of reinforcements (intrinsic, extrinsic) work with what kinds of groups, and why. If operant theory is to be useful to teachers and other practitioners, much more precise information is needed on the value of different kinds of reinforcers

and about optimum scheduling of reinforcement for rapid learning and for retention. It should also be recognized that the type of material to be learned is another important variable that may affect learning rate and retention. Research on the effects of reinforcement on language have, for the most part, been confined to vocabulary and grammar, with little attention being paid to comprehension. Yet comprehension is the crux of both spoken and written language, and should be investigated within the behaviorist's theoretical framework.

Meaningfulness of material is an important factor in reading but not an easy one to assess in terms of its interaction with other variables. Since programmed instruction, which is a direct outgrowth of operant-conditioning principles, moves by small progressions from the simple to the complex, the interaction of these two dimensions should be studied. As noted earlier, in word recognition those words which appear simple and are used most frequently in ordinary discourse are not necessarily the easiest to read or the most meaningful to the child. The dimension of meaningfulness calls for a knowledge of children's intellectual development, an area with which the behaviorist has not been noticeably concerned.

Staats has suggested that, unlike the learning of speech, learning to read is attended by a variety of aversive stimuli, to the extent that motivation may be a more important variable in reading deficiency than lack of ability or deficiencies in previous learning. Here again, the study of motivation must lead to an examination of the relationship between the aversiveness of stimuli and the child's level of development as it affects his interests, attitudes, etc. Reading is not an inherently distasteful activity, but it can easily become so if the activities associated with it are boring and unproductive from the child's point of view.

As with reinforcement, the role of imitation in language learning has not been fully determined. Research in this area has tended to concentrate on the imitation of models who exhibit certain types of behavior, e.g., aggression. More work is needed on the imitation of language behavior, especially as this is affected by social class, status of models to be imitated, age of subjects, and so on. McNeill suggests that children imitate the language of adults in a very general manner, much as an aspiring author may imitate the style of Faulkner. While this analogy may be instructive, it leaves open the precise nature of this imitation--exactly what aspects of language are learned by imitation, by what mechanisms it operates, and what are the variables that significantly affect it. In their zeal to discount the role of imitation as part of the attempt to discredit learning-theory accounts of language, linguists have tended to dismiss imitation completely as a significant factor. Unless one adopts

the position that virtually the whole of language is "preprogrammed" (i.e., the result of innate universals), as McNeill does, for example, it seems unnecessary to dismiss imitation as a learning principle from one's account of language learning. This is a position that to many theorists appears untenable. However, we need to know which aspects of language are most amenable to learning by imitation (e.g., vocabulary, phonetics, etc.) and at what age imitation learning may be most effectively implemented. While some of the immediate findings of studies using operant conditioning methods appear impressive, research is needed to determine both long-term effects and possible side effects. Few, if any, longitudinal studies on this subject have appeared in the literature.

Currently, cognitive and psycholinguistic models appear to provide promising leads in the study of language and reading. We have already noted the excitement and productivity which has characterized the study of children's language in the past decade, as a result of psycholinguistic theories. Much is now known about children's acquisition of vocabulary and syntax during the early years, and this research has either been generated as a result of the psycholinguistic models or has been reinterpreted within their theoretical framework. Most of the models presume a relatively complete language system by the time the child is about four years old. Consequently, little work has been done until quite recently on language development during the elementary years (five to ten years) especially as it is affected by educational factors. Such evidence as there is (e.g., C. Chomsky, 1970; Elkind, 1970) shows that there is considerable growth in the acquisition of complex language competence during these years, but the relationship to development of reading ability is less clear. More information of this kind is sorely needed.

Perhaps the most critical area, and one which has been relatively neglected, however, is the study of the relationship between the deep and surface structure of sentences as this relationship is manifested in the process of reading. The process by which the fluent reader is seemingly able to bypass (or maybe telescope) the processes of letter discrimination and word identification and yet derive meaning is still a mystery. But, at the same time, it is also the crux of the reading act. One approach to solving the mystery might be to investigate what language variables contribute to this ability; e.g., whole-word recognition, a fluent speaking vocabulary, exposure to literary materials such as stories in the home, and even televised games that concentrate on word, phrase, and sentence recognition. These may be used to teach children to look for and expect syntactic and semantic patterns in written prose.

There seems to be considerable agreement among linguists that the language-acquisition process is largely

accomplished by the time the child reaches the age of four or five. Assuming that some aspects of this process are learned through exposure to native speakers, the effects of intervention programs which expose dialect-speaking children of this age range to standard English-speaking models need to be assessed. Programs should be developed that aim to teach language (comprehension and speech) as a communication tool to be used in the context of solving problems--intellectual, emotional, and social.

If we adopt the position taken by Goodman, Smith, and others that reading is a process of acquiring information from printed materials, a logical step in understanding reading is to look at the growth of intellectual development, especially those processes which enter most conspicuously into reading, such as problem solving, critical thinking, and even creativity. The "psycholinguistic guessing game" would seem to be not unlike the process called divergent thinking, which some authors believe to be a major factor in creativity. Correct identification of words and letters (the process by which the majority of children learn to read) is obviously more akin to the process of convergent thinking.

While much is known about children's intellectual development in terms of the theories of Piaget and Bruner, the role of language in cognition and the role of cognition in language growth need more precise study. Since both these factors loom so large in the reading process, their interaction must inevitably be of some concern to the researcher trying to understand the nature of reading.

The competence-performance distinction seems to be particularly useful with so-called nonverbal children. If a child speaks only in his own dialect but understands perfectly when he hears standard English, he should, theoretically, have an advantage over the child who understands only dialect when it comes to learning to read. We, therefore, need more sophisticated tools for testing a child's comprehension, especially at the younger ages. Some ingenious tests of a child's comprehension of major grammatical classes, negation, etc., which were described in the section on competence and performance, should point the way to new efforts of this kind. The tests themselves might be used to suggest comprehension games which the inventive teacher could use to facilitate communication with nonspeaking children. If Chomsky is correct in his assertion that only the surface structures of languages differ, while on their deeper levels all languages are of the same universally human character, we should capitalize on these universal features to help children understand that all languages are rooted in certain basic common experiences and that reading and writing, like speech, are useful tools for communicating these experiences. Research is needed to clarify the psychological correlates of the hypothesized deep

structure and transformational operations involved in extracting meaning either from the flow of speech or writing. Information-processing models of greater sophistication, which simulate the complexity of factors involved, would also be helpful in elucidating the processes taking place when a person understands what he hears or reads.

Basically, we are in no position to say that any of the models reviewed give a completely satisfactory account of children's language. Correspondingly, no satisfactory model of the reading process exists either. We need more longitudinal studies of children's speech development from infancy to adolescence. More studies are needed of children's spontaneous language and writing as these interact with their early experience with reading. But we also need short-range studies to test and refine the models as well as to replicate the findings now in the literature.

Above all, we need to remember that no model, however comprehensive or elegant, can take account of individual or group differences. It is the essence of a model that it describes an abstraction--the "ideal," or the "normal." A model can only depict what is universal, but universals are overlaid by the effects of countless group and individual variables. While this review has addressed itself strictly to models and the research pertaining to models, it is fully recognized that there is a large and growing body of important research literature on socioeconomic and other group differences in language. This work should be continued and expanded. At the same time, there should be some attempt to incorporate the findings from this research into the theoretical framework of the models reviewed.

REFERENCES

Anderson, S. A., & Beh, W. The reorganization of verbal memory in childhood. Journal of Verbal Learning and Verbal Behavior, 1968, 7, 1049-1053.

Bandura, A. Behavioral modification through modeling procedures. In L. Krasner & L. Ullman (Eds.), Research in behavior modification. New York: Holt, Rinehart, & Winston, 1965.

Bandura, A., & Menlove, F. L. Factors determining vicarious extinction of avoidance behavior through symbolic modeling. Journal of Personality and Social Psychology, 1968, 5, 99-108.

Bandura, A., & Walters, R. H. Social learning and personality development. New York: Holt, Rinehart, & Winston, 1963.

Bar-Hillel, Y. Language and information. Reading, Mass.: Addison-Wesley, 1964.

Bassin, F. V., & Bein, E. S. Application of electromyography to the study of speech. In N. O'Connor (Ed.), Recent Soviet psychology. New York: Liveright, 1961.

Beilin, H., Kagan, J., & Rabinowitz, R. Effects of verbal and perceptual training on water level representation. Child Development, 1966, 37, 317-328.

Bellugi, U. The emergence of inflections and negation systems in the speech of two children. Paper presented at the meeting of the New England Psychological Association, Boston, 1964.

Bellugi, U. The development of interrogative structure in children's speech functions. In K. Riegel (Ed.), The development of language functions. Ann Arbor: University of Michigan Press, 1965.

Bellugi, U. The acquisition of negation. Unpublished doctoral dissertation, Harvard University, 1967.

Bem, D. J., & Bem, S. L. Nativism revisited: A review of E. H. Lenneberg, Biological foundations of behavior. Journal of the Experimental Analysis of Behavior, 1968, 11, 497-501.

Bereiter, C., & Engelmann, S. Teaching disadvantaged children in the preschool. Englewood Cliffs, N. J.: Prentice-Hall, 1966.

Berko, J. The child's learning of English morphology. Word, 1958, 14, 150-177.

Bever, T. G. The cognitive basis for linguistic structures. In J. R. Hayes (Ed.), Cognition and the development of language. New York: Wiley, 1970.

Bever, T. G., Fodor, J. A., & Weksel, W. On the acquisition of syntax: A critique of "contextual generalization." Psychological Review, 1965, 72, 467-482.

Bever, T. G., Mehler, J., & Epstein, J. What children do in spite of what they know. Science, 1968, 921-924.

Bever, T. G., Mehler, J., & Valian, V. V. Linguistic capacity of very young children. Lecture presented at Harvard University, 1967.

Blank, M., & Solomon, F. Tutorial language problem to develop abstract thinking in socially disadvantaged children. Child Development, 1968, 39, 379-390.

Blank, M., & Solomon, F. How shall the disadvantaged child be taught? Child Development, 1969, 40, 47-61.

Bloom, L. M. Why not pivot grammar? Journal of Speech and Hearing Disorders, 1971, 36, 40-50.

Bloom, R. W. Learning to read as viewed from an operant perspective. Paper presented at the meeting of the American Educational Research Association, New York, 1971.

Blount, B. G. Acquisition of language by Luo children. Unpublished doctoral dissertation, University of California, Berkeley, 1969.

Blumental, A. L. Language and psychology: Historical aspects of psycholinguistics. New York: Wiley, 1970.

Boat, B. H., & Clifton, C., Jr. Verbal mediation in four-year-old children. Child Development, 1968, 39, 505-514.

Bogoiavlensky, D. N. The psychology of understanding. In B. Simon (Ed.), Psychology in the Soviet Union. Stanford: Stanford University Press, 1957. Pp. 69-83.

Braine, M. D. S. The ontogeny of English phrase structure: The first phase. Language, 1963, 39, 1-13.

Braine, M. D. S. On the basis of phrase structure: A reply to Bever, Fodor, and Weksel. Psychological Review, 1965, 72, 483-492.

Brown, E. R. Bases of reading acquisition. Reading Research Quarterly, 1970, 6, 49-74.

Brown, R. W. Linguistic determinism and the part of speech. Journal of Abnormal and Social Psychology, 1957, 55, 1-5.

Brown, R. W. Words and things. Glencoe, Ill.: Free Press, 1958.

Brown, R. W., & Bellugi, U. Three processes in the child's acquisition of syntax. Harvard Educational Review, 1964, 34, 133-151.

Brown, R. W., & Fraser, C. C. The acquisition of syntax: In U. Bellugi & R. W. Brown (Eds.), The acquisition of language. Monographs of the Society for Research in Child Development, 1964, 29.

Brown, R., & Hanlon, C. Derivational complexity and order of acquisition in child speech. In J. R. Hayes (Ed.), Cognition and the development of language. New York: Wiley, 1970.

Brown, R. W., Black, A. H., & Horowitz, A. E. Phonetic symbolism in national languages. Journal of Abnormal and Social Psychology, 1955, 50, 388-393.

Brown, R. W., Cazden, C. B., & Bellugi, U. The child's grammar from I to III. In J. B. Hill (Ed.), Minnesota symposium on child psychology. Minneapolis: University of Minnesota Press, 1968.

Bruner, J. S., Goodnow, J. J., & Austin, M. Studies in cognitive growth. New York: Wiley, 1966.

Carlson, P., & Anisfeld, M. Some observations on the linguistic competence of a two-year-old. Child Development, 1969, 40, 569-575.

Carmichael, L., Hogan, H. P., & Walter, A. A. An experimental study of the effect of language on the representation of visually perceived form. Journal of Experimental Psychology, 1932, 15, 73-86.

Carroll, J. B. An operational model for language behavior. Anthropological Linguistics, 1959, 1, 37-54.

Carroll, J. B. Language and thought. Englewood Cliffs, N. J.: Prentice-Hall, 1964. (a)

Carroll, J. B. The analysis of reading instruction: Perspectives from psychology and linguistics. In E. R. Hilgard (Ed.), Sixty-third yearbook of the National Society for the Study of Education. (Part I) Chicago: University of Chicago Press, 1964. (b)

Carroll, J. B. Words, meanings, and concepts. Harvard Educational Review, 1964, 34, 178-202. (c)

Carroll, J. B. Some neglected relationships in reading and language learning. Elementary English, 1966, 43, 577-582.

Carroll, J. B. Man is born to speak. Contemporary Psychology, 1968, 13, 117-119.

Carroll, J. B. The nature of the reading process. In E. O. Calkins (Ed.), Reading Forum, Monograph No. 11, National Institute of Neurological Diseases and Stroke, 1970.

Cazden, C. B. The acquisition of noun and verb inflections. Child Development, 1968, 39, 433-448.

Cazden, C. B. Suggestions from studies of early language acquisition. Childhood Education, 1969, 46, 127-131.

Chase, W. G., & Clark, H. H. Mental operations in the comparison of sentences and pictures. In L. Gregg (Ed.), Cognition in learning and memory. New York: Wiley, 1970.

Chomsky, C. The acquisition of syntax in children from 5 to 10. Research Monograph, No. 57. Cambridge, Mass.: M.I.T. Press, 1970. (a)

Chomsky, C. Reading, writing, and phonology. Harvard Educational Review, 1970, 40, 287-309. (b)

Chomsky, N. A. Syntactic structures. The Hague: Mouton, 1957.

Chomsky, N. A. Review of B. F. Skinner, Verbal behavior. Language, 1959, 35, 26-58.

Chomsky, N. A. Some methodological remarks on generative grammar. Word, 1961, 17, 219-239.

Chomsky, N. A. Current issues in linguistic theory. The Hague: Mouton, 1964.

Chomsky, N. A. Aspects of a theory of syntax. Cambridge, Mass.: M.I.T. Press, 1965.

Chomsky, N. A. Cartesian linguistics: A chapter in the history of rationalist thought. New York: Harper & Row, 1966.

Chomsky, N. A. Language and mind. New York, Harcourt, Brace, & World, 1968.

Chomsky, N. A., & Halle, M. The sound pattern of English. New York: Harper & Row, 1968.

Chomsky, N. A., & Miller, G. A. Introduction to the formal analysis of natural languages. In R. D. Luce, R. R. Bush, & E. Galanter (Eds.), Handbook of mathematical psychology. Vol. 2. New York: Wiley, 1963. Pp. 269-321.

Deese, J. Psycholinguistics. Boston: Allyn & Bacon, 1970.

De Laguna, G. A. Speech: Its function and development. Bloomington: Indiana University Press, 1927.

Denes, P. B. On the statistics of spoken English. Journal of the Acoustical Society of America, 1963, 3, 892-904.

Dixon, T. R., & Horton, D. L. Verbal behavior and general behavior theory. Englewood Cliffs, N. J.: Prentice-Hall, 1968.

Dollard, J., & Miller, N. E. Personality and psychotherapy. New York: McGraw-Hill, 1950.

Downing, J. The perception of linguistic structures in learning to read. British Journal of Educational Psychology, 1969, 39, 267-271.

Downing, J. Children's concept of language in learning to read. Educational Research, 1970, 12, 106-112.

Eimas, P. D., Siqueland, E. R., Jusczyk, P., & Vigorito, J. Speech perception in infants. Science, 1971, 171, 303-306.

Elkind, D. Reading, logic, and perception: An approach to reading instruction. In D. Elkind (Ed.), Children and adolescents: Interpretive essays on Jean Piaget. New York: Oxford University Press, 1970.

Elkind, D., & Deblinger, J. Perceptual training and reading achievement in disadvantaged children. Child Development, 1969, 40, 11-19.

Elkonin, D. B. The psychology of higher nervous activity and child psychology. In B. Simon (Ed.), Psychology in the Soviet Union. Stanford: Stanford University Press, 1957. Pp. 47-68.

Epstein, W. Some conditions of the influence of syntactual structure on learning, grammatical transformation, learning instructions, and "chunking." Journal of Verbal Learning and Verbal Behavior, 1967, 6, 415-419.

Ervin, S. M. Imitation and structural change in children's language. In E. H. Lenneberg (Ed.), New directions in the study of language. Cambridge, Mass.: M.I.T. Press, 1964.

Ervin, S. M., & Miller, W. F. Language development. In H. W. Stevenson (Ed.), Child psychology. Chicago: University of Chicago Press, 1963. Pp. 108-143.

Ervin-Tripp, S. M. Language development. In M. Hoffman & L. Hoffman (Eds.), Review of child development research. Vol. 2. Ann Arbor: University of Michigan Press, 1966. Pp. 55-105.

Ervin-Tripp, S. M. Discourse agreement: How children answer questions. In J. R. Hayes (Ed.), Cognition and the development of language. New York: Wiley, 1970.

Ervin, Tripp, S. M., & Slobin, D. I. Psycholinguistics. In P. R. Farnsworth, O. McNemar, & Q. McNemar (Eds.), Annual review of psychology. Palo Alto, Calif.: Annual Reviews, 1966. Pp. 435-474.

Fant, G. Auditory patterns of speech. In W. Wathen-Dunn (Ed.), Models for perception of speech and visual form. Cambridge, Mass.: M.I.T. Press, 1967.

Feigenbaum, E. Information processing and memory. In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970.

Feigenbaum, E. A., & Feldman, J. (Eds.) Computers and thought. New York: McGraw-Hill, 1963.

Ferguson, C. A. Baby talk in six languages. American Anthropologist, 1964, 66, 103-114.

Fillenbaum, S. Psycholinguistics. In P. H. Mussen & M. R. Rosenzweig (Eds.), Annual review of psychology. Palo Alto, Calif.: Annual Reviews, 1971. Pp. 251-308.

Flavell, J. H. Concept formation. In P. H. Mussen (Ed.), Carmichael's manual of child psychology. Vol. 1. (3rd ed.) New York: Wiley, 1970. Pp. 983-1060.

Fodor, J. A. Review of H. Werner & B. Kaplan, Symbol formation. Language, 1964, 4, 566-578.

Fodor, J. A. Could meaning be a r_m? Journal of Verbal Learning and Verbal Behavior, 1965, 4, 73-81.

Fodor, J. A. How to learn to talk: Some simple ways. In F. Smith & G. A. Miller (Eds.), The genesis of language: A psycholinguistic approach. Cambridge, Mass.: M.I.T. Press, 1966.

Fodor, J. A. Current approaches to syntax recognition. In Perception of language, a symposium of the Learning Research and Development Center, University of Pittsburgh, 1969.

Fodor, J. A., & Bever, T. G. The psychological reality of linguistic segments. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 4-20.

Fodor, J. A., & Garrett, M. Some syntactic determinants of sentential complexity. Perception and Psychophysics, 1966, 1, 30-32.

Fraser, C. C. Comments in response to McNeill's "The creation of language by children." In J. Lyons & R. Wales (Eds.), Psycholinguistics papers. Edinburgh: University of Edinburgh Press, 1966.

Fraser, C. C., Bellugi, U., & Brown, R. W. Control of grammar in imitation, comprehension, and production. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 121-135.

Furth, H. Piaget and knowledge. Englewood Cliffs, N. J.: Prentice-Hall, 1969.

Furth, H. Piaget for teachers. Englewood Cliffs, N. J.: Prentice-Hall, 1970.

Furth, H., & Milgram, N. The influence of language on classification: A theoretical model applied to normal, retarded, and deaf children. Genetic Psychology Monographs, 1965, 72, 317-351.

Gardner, R. A., & Gardner, B. T. Teaching sign language to a chimpanzee. Science, 1969, 165, 664-672.

Garrett, M., Bever, T. G., & Fodor, J. A. The active use of grammar in speech perception. Perception and Psychophysics, 1966, 1, 30-32.

Gephart, W. J. Application of the convergence technique to basic studies of the reading process. Bloomington, Ind.: Phi Delta Kappa, 1970.

Gibson, E. J. Learning to read. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 315-354.

Gibson, E., Gibson, J., Pick, A., & Osser, H. A developmental study of the discrimination of letter-like forms. Journal of Comparative and Physiological Psychology, 1962, 55, 897-906.

Glanzer, M. Grammatical category: A rote learning and word association analysis. Journal of Verbal Learning and Verbal Behavior, 1962, 1, 31-41.

Glucksberg, S., Krauss, R., & Weisberg, R. Referential communication in nursery-school children: Method and some preliminary findings. Journal of Experimental Child Psychology, 1966, 3, 333-342.

Goodman, K. S. A linguistic study of cues and miscues in reading. Elementary English, 1965, 42, 639-643.

Goodman, K. (Ed.) The psycholinguistic nature of the reading process. Detroit: Wayne State University Press, 1968. Pp. 15-26.

Goodman, K. S. Reading: A psycholinguistic guessing game. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 259-272.

Gough, P. B. Grammatical transformations and the speed of understanding. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 107-111.

Gray, B. B., & Fygentakis, L. The development of language as a function of programmed conditioning. Behavioral Research and Therapy, 1968, 6, 455-460.

Harlow, H. F. Manipulatory motivations in the infant rhesus monkey. Journal of Comparative and Physiological Psychology, 1965, 56, 22-30.

Hart, B. M., & Risley, T. R. Use of descriptive adjectives in the speech of preschool children. Journal of Applied Behavior Analysis, 1968, 1, 109-120.

Hayes, J. R. (Ed.) Cognition and the development of language. New York: Wiley, 1970.

Hayes, J. R., & Clark, H. Experiments on the segmentation of an artificial speech analogue. In J. R. Hayes (Ed.), Cognition and the development of language. New York: Wiley, 1970.

Hebb, D. O. The organization of behavior. New York: Wiley, 1949.

Hilgard, E. R., & Bower, G. Theories of learning. (2nd ed.) New York: Appleton-Century-Crofts, 1966.

Hockett, C. F., & Altmann, S. A. A note on design features. In T. A. Sebeok (Ed.), Animal communication. Bloomington: Indiana University Press, 1968. Pp. 61-72.

Holmes, J. A., & Singer, H. Speed and power in reading in high school students. Washington, D.C.: U.S. Government Printing Office, 1966. (Cooperative Research Monograph, No. 14)

Holt, J. A little learning: Review of J. S. Bruner, Toward a theory of instruction. New York Review of Books, May, 1966.

Huttenlocher, J., Eisenberg, K., & Strauss, S. Comprehension: Relation between perceived action and logical subject. Journal of Verbal Learning and Verbal Behavior, 1968, 7, 527-530.

Jakobson, R. Kindersprache, Aphasie, und allgemeine Lautgesetze. Uppsala: Almquist & Wekseil, 1941.

Jakobson, R. Child language, aphasia, and general sound laws. (Translated by A. Keiler) The Hague: Mouton, 1968.

Jakobson, R., & Halle, M. Fundamentals of language. The Hague: Mouton, 1956.

Jenkins, J. J. The challenge to psychological theorists. In T. R. Dixon & D. L. Horton (Eds.), Verbal behavior and general behavior theory. Englewood Cliffs, N. J.: Prentice-Hall, 1968.

Jenkins, J. J., & Palermo, D. S. Mediation processes and the acquisition of linguistic structure. Monographs of the Society for Research in Child Development, 1964, 29, 141-169.

Jenkins, J. J., Foss, D. J., & Greenberg, J. H. Phonological distinctive features as cues in learning. Journal of Experimental Psychology, 1968, 77(2), 200-205.

Jensen, A. R. Conceptions and misconceptions about verbal mediation. Proceedings, Claremont Reading Conference, 1966, 30, 134-141.

Johnson, N. F. The psychological reality of phrase-structure rules. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 469-475.

Kagan, J. Dyslexia and its remediation. In E. O. Calkin (Ed.), Reading forum, NINDS Monograph, No. 11, 1970.

Katz, J. The philosophy of language. New York: Harper & Row, 1966.

Kelley, K. L. Early syntactic acquisition. Santa Monica: Rand Corporation, 1967.

Kernan, K. T. The acquisition of language by Samoan children. Unpublished doctoral dissertation, University of California, Berkeley, 1969.

Klima, E. S., & Bellugi, U. Syntactic regularities in the speech of children. In J. Lyons & R. Wales (Eds.), Psycholinguistics papers. Edinburgh: University of Edinburgh Press, 1966.

Kohlberg, L., Yaeger, J., & Hjertholm, E. Private speech: Four studies and a review of theories. Child Development, 1968, 39, 671-690.

Kohnstamm, G. A. Piaget's analysis of class inclusions: Right or wrong? The Hague: Mouton, 1967.

Krech, D. Psychobioneurochemeducation. PTA Magazine, April-May, 1969.

Labov, W. Social factors in learning standard English. In R. W. Shuy (Ed.), Social dialects and language learning. Champaign, Ill.: National Council of Teachers of English, 1964.

Ladefoged, P., & Broadbent, D. E. Perception of sequence in auditory events. Quarterly Journal of Experimental Psychology, 1960, 162-170.

Lashley, K. S. The problem of serial order in behavior. In L. A. Jeffress (Ed.), Cerebral mechanisms in behavior. New York: Wiley, 1951. Pp. 112-136.

Lawton, D. Social class, language, and education. New York: Schocken, 1968.

Lenneberg, E. H. Understanding language without the ability to speak. Journal of Abnormal and Social Psychology, 1962, 65, 419-425.

Lenneberg, E. H. Biological perspectives of language. In E. H. Lenneberg (Ed.), New directions in the study of language. Cambridge, Mass.: M.I.T. Press, 1964. (a)

Lenneberg, E. H. (Ed.) New directions in the study of language. Cambridge, Mass.: M.I.T. Press, 1964. (b)

Lenneberg, E. H. Biological foundations of language. New York: Wiley, 1967.

Lenneberg, E. H., Nichols, I. A., & Rosenberger, E. F. Primitive stages of language development in mongolism. In Disorders of Communication. Baltimore: Williams & Wilkins, 1964. P. 42.

Leopold, W. F. Speech development of a bilingual child: 1. Vocabulary growth in the first two years. Evanston: Northwestern University Press, 1939.

Leopold, W. F. Speech development of a bilingual child: 2. Sound learning in the first two years. Evanston: Northwestern University Press, 1947.

Leopold, W. F. Speech development of a bilingual child: 3. Grammar and general problems in the first two years. Evanston: Northwestern University Press, 1949. (a)

Leopold, W. F. Speech development of a bilingual child: 4. Diary from age 2. Evanston: Northwestern University Press, 1949. (b)

Levelt, W. J. M. Hierarchical chunking in sentence processing. Perception and Psychophysics, 1970, 8, 99-103.

Lindsay, R. K. Inferential memory as the basis of machines which understand natural language. In E. A. Feigenbaum & J. Feldman (Eds.), Computers and thought. New York: McGraw-Hill, 1963.

Lovell, K., & Dixon, E. M. The growth of control of grammar in imitation, comprehension, and production. Journal of Child Psychology and Psychiatry and Allied Disciplines, 1967, 8, 31-39.

Luria, A. R., & Leontiev, A. A., Jr. An enduring psycholinguistic contribution. Contemporary Psychology, 1969, 14, 580.

McCarthy, D. Language development in children. In L. Carmichael (Ed.), Manual of child psychology. New York: Wiley, 1954.

McCawley, J. D. The role of semantics in a grammar. In E. Bach & R. T. Harms (Eds.), Universals in linguistic theory. New York: Holt, Rinehart, & Winston, 1968. Pp. 125-170.

MacCorquodale, K. B. F. Skinner's Verbal behavior: A retrospective appreciation. Journal of Experimental Analysis of Behavior, 1969, 12, 831-841.

MacCorquodale, K. On Chomsky's review of Skinner's Verbal behavior. Journal of Experimental Analysis of Behavior, 1970, 13, 83-99.

McMahon, L. E. Grammatical analysis as part of understanding a sentence. Unpublished doctoral dissertation, Harvard University, 1963.

McNeill, D. The creation of language by children. In J. Lyons & R. Wales (Eds.), Psycholinguistics papers. Edinburgh: University of Edinburgh Press, 1966. (a)

McNeill, D. Developmental psycholinguistics. In F. Smith & G. A. Miller (Eds.), The genesis of language: A psycholinguistic approach. Cambridge, Mass.: M.I.T. Press, 1966. Pp. 15-84. (b)

McNeill, D. On theories of language acquisition. In T. R. Dixon & D. L. Horton (Eds.), Verbal behavior and general behavior theory. Englewood Cliffs, N. J.: Prentice-Hall, 1968. (a)

McNeill, D. Two problems for cognitive psychologists. Problem 1: Predication. Colloquium at the Center for Cognitive Studies, Harvard University, 1968. (b)

McNeill, D. The development of language. In P. H. Mussen (Ed.), Carmichael's manual of child psychology. Vol. 1. (3rd ed.) New York: Wiley, 1970. Pp. 1061-1161.

Mandler, G. New directions in psychology. Vol. 3. New York: Holt, Rinehart, & Winston, 1967.

Mandler, G., & Mandler, J. Thinking: From association to Gestalt. New York: Wiley, 1964.

Mehler, J. Some effects of grammatical transformations on the recall of English sentences. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 346-351.

Mehler, J., & Carey, P. Role of surface and base structure in the perception of sentences. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 335-338.

Mehler, J., & Miller, G. A. Retroactive interference in the recall of simple sentences. British Journal of Pyschology, 1964, 55, 295-302.

Menyuk, P. A preliminary evaluation of grammatical capacity in children. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 429-439. (a)

Menyuk, P. Syntactic structures in the language of children. Child Development, 1963, 34, 407-422. (b)

Meumann, E. Die Sprache des Kindes. Zurich: Zurcher and Furrer, 1894.

Miller, G. A. The magical number seven, plus or minus two. Psychological Review, 1956, 63, 81-97.

Miller, G. A. Some psychological studies of grammar. American Psychologist, 1962, 17, 748-762.

Miller, G. A. The psychology of communication: Seven essays. Baltimore: Penguin Books, 1967.

Miller, G. A. Theoretical psycholinguistics. In G. Lindzey & E. Aronson (Eds.), Handbook of social psychology. Vol. 3. Reading, Mass.: Addison-Wesley, 1969.

Miller, G. A., & Chomsky, N. A. Finitary models of language users. In R. Luce (Ed.), Handbook of mathematical psychology. New York: Wiley, 1963.

Miller, G. A., & McNeill, D. Psycholinguistics. In G. Lindzey & E. Aronson (Eds.), Handbook of social psychology. Vol. 3. (2nd ed.) Reading, Mass.: Addison-Wesley, 1969. Pp. 666-794.

Miller, G. A., & Selfridge, J. A. Verbal context and the recall of meaningful material. American Journal of Psychology, 1950, 63, 176-185.

Miller, G. A., Heise, G. A., & Lichten, W. The intelligibility of speech as a function of the context of the test materials. Journal of Experimental Psychology, 1951, 41, 329-335.

Miller, G. A., McKean, K., & Slobin, D. I. The exploration of transformations by sentence matching. In G. A. Miller, Some psychological studies of grammar. American Psychologist, 1962, 17, 748-762.

Miller, N. E., & Dollard, J. Social learning and imitation. New Haven: Yale University Press, 1941.

Miron, M. S. A cross-linguistic investigation of phonetic symbolism. Journal of Abnormal and Social Psychology, 1961, 62, 623-630.

Moskovitz, S. T. Some assumptions underlying the Bereiter approach. Young Children, 1968, 23, 24-31.

Moskowitz, A. I. The two-year-old stage in the acquisitions of English phonology. Project on Linguistic Analysis, 2nd series, No. 9, 1969.

Mowrer, O. H. Hearing and speaking: An analysis of language learning. Journal of Speech and Learning Disorders, 1948, 23, 143-152.

Mowrer, O. H. The psychologist looks at language. American Psychologist, 1954, 9, 660-694.

Mowrer, O. H. Learning theory and the symbolic processes. New York: Wiley, 1960.

Newell, A., Shaw, J. C., & Simon, H. A. Elements of a theory of human problem solving. Psychological Review, 1958, 65, 151-166.

Norman, D. A. (Ed.) Models of human memory. New York: Academic Press, 1970.

Novikova, L. A. Electrophysiological investigation of speech. In N. O'Connor (Ed.), Recent Soviet psychology. New York: Liveright, 1961.

Olson, D. R. Language and thought: Aspects of a cognitive theory of semantics. Psychological Review, 1970, 77, 257-273.

Osborn, J. Teaching a teaching language to disadvantaged children. In M. C. Templin (Ed.), Monographs of the Society for Research in Child Development. Chicago: University of Chicago Press, 1968.

Osgood, C. E. The nature of measurement of meaning. Psychological Bulletin, 1952, 49, 197-237.

Osgood, C. E. Motivational dynamics of language behavior. In M. R. Jones (Ed.), Nebraska symposium on motivation. Lincoln: University of Nebraska Press, 1957.

Osgood, C. E. Toward a wedding of insufficiencies. In T. R. Dixon & D. L. Horton (Eds.), Verbal behavior and general behavior theory. Englewood Cliffs, N. J.: Prentice-Hall, 1968.

Osgood, C. E. The nature and measurement of meaning. In J. S. Snider & C. E. Osgood (Eds.), Semantic differential techniques. Englewood Cliffs, N. J.: Prentice-Hall, 1969. Pp. 406-420.

Osgood, C. E., Suci, G. J., & Tannenbaum, P. H. The measurement of meaning. In J. S. Snider & C. E. Osgood (Eds.), Semantic differential techniques. Englewood Cliffs, N. J.: Prentice-Hall, 1969.

Penfield, W., & Roberts, L. Speech and brain mechanisms. Princeton, N. J.: Princeton University Press, 1959.

Peterson, G. E., & Barney, H. L. Control methods used in a study of vowels. Journal of the Acoustical Society of America, 1952, 24, 175-184.

Piaget, J. On the development of memory and identity. Barre, Mass.: Clark University Press, 1968.

Piaget, J. Piaget's theory. In P. H. Mussen (Ed.), Carmichael's manual of child psychology. Vol. 1. (3rd ed.) New York: Wiley, 1970. Pp. 703-732. (a)

Piaget, J. Science of education and the psychology of the child. New York: Orion, 1970. (b)

Piaget, J., & Inhelder, B. The psychology of the child. New York: Basic Books, 1969.

Potts, M. The effects of a morphological cue and of distinctive verbal labels on the transposition responses of three-, four-, and five-year-olds. Journal of Experimental Child Psychology, 1968, 6, 75-86.

Premack, D. The education of Sarah: A chimpanzee learns the language. Psychology Today, 1970, 4(4), 54-58.

Quillian, M. R. The teachable language comprehender: A simulation program and theory of language. Communications of the Association of Computer Machinists, 1969, 12, 459-476.

Reber, A. S., & Anderson, J. R. The perception of clicks in linguistic and nonlinguistic messages. Perception and Psychophysics, 1970, 8, 81-89.

Reese, H. W. Verbal mediation as a function of age level. Psychological Bulletin, 1962, 59, 502-509.

Reitman, W. What does it take to remember? In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970.

Ruddell, R. B. The effect of the similarity of oral and written patterns of language structure on written comprehension. Elementary English, 1965, 42, 403-410.

Ruddell, R. B. Psycholinguistic implications for a systems of communication model. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 239-258.

Sapon, S. M. Shaping productive verbal behavior in a non-speaking child: A case report. Georgetown University Monograph Series, No. 19, 1966.

Savin, H. B., & Perchonok, E. Grammatical structure and the immediate recall of English sentences. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 348-353.

Schwarcz, R. M. Steps toward a model of linguistic performance: A preliminary sketch. Mechanical Translation, 1967, 10, 37-52.

Scott, J. P. Critical periods in behavior development. Science, 1962, 138, 949-958.

Shipley, E. F., Smith, C., & Gleitman, L. A study in the acquisition of language: Free responses to commands. Language, 1969, 45, 322-343.

Simmons, R. F., & Burger, J. F. A semantic analyzer for English sentences. Mechanical Translation, 1969, 3, 1-13.

Simon, H., & Kotovsky, K. Human acquisition of concepts for sequential patterns. Psychological Review, 1963, 70, 534-546.

Sinclair-de Zwart, M. Acquisition de language et developpement de la pensee. Paris: Dumod, 1967.

Singer, H. Substrata-factor patterns accompanying development in power of reading, elementary through college levels. In E. Thurston & L. Hafner (Eds.), Philosophical and sociological bases of reading. Milwaukee: National Reading Conference, 1964. Pp. 41-56.

Singer, H., & Ruddell, R. B. Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970.

Skinner, B. F. Verbal behavior. New York: Appleton-Century-Crofts, 1957.

Skinner, B. F. Operant behavior. In W. K. Honig (Ed.), Operant behavior: Areas of research and application. New York: Appleton-Century-Crofts, 1966.

Skinner, B. F. Contingencies of reinforcement: A theoretical analysis. New York: Appleton-Century-Crofts, 1969.

Slobin, D. I. Imitation and the acquisition of syntax. Paper presented at the Second Research Planning Conference, Project Literacy, Cornell University, 1964.

Slobin, D. I. The acquisition of Russian as a native language. In F. Smith & G. A. Miller (Eds.), The genesis of language. Cambridge, Mass.: M.I.T. Press, 1966. (a)

Slobin, D. I. Comments on developmental linguistics: A discussion of McNeill's presentation. In F. Smith & G. A. Miller (Eds.), The genesis of language. Cambridge, Mass.: M.I.T. Press, 1966. (b)

Slobin, D. I. Grammatical transformations and sentence comprehension in childhood and adulthood. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 219-227. (c)

Slobin, D. I. Soviet psycholinguistics. In N. O'Connor (Ed.), Present-day Russian psychology: A symposium by seven authors. Oxford: Pergamon Press, 1966. Pp. 109-151. (d)

Slobin, D. I. Autonemic phonetic symbolism in natural languages. Journal of Personality and Social Psychology, 1968, 10, 301-305.

Slobin, D. I. Early grammatical development in several languages, with special attention to Soviet research. In W. Weksel & T. G. Bever (Eds.), The structure and psychology of language. New York: Holt, Rinehart, & Winston, 1970.

Slobin, D. I. The ontogenesis of grammar: Facts and theories. New York: Academic Press, 1971. (a)

Slobin, D. I. Psycholinguistics. Glenview, Ill.: Scott, Foresman, 1971. (b)

Slobin, D. I., & Welsh, C. A. Elicited imitation as a research tool in developmental psycholinguistics. Unpublished paper, Department of Psychology, University of California, Berkeley, 1967.

Smith, F. Understanding reading: A psycholinguistic analysis of reading and learning to read. New York: Holt, Rinehart, & Winston, 1971.

Smith, F., & Miller, G. A. (Eds.) The genesis of language: A psycholinguistic approach. Cambridge, Mass.: M.I.T. Press, 1966.

Spiker, C. C. Verbal factors in the discrimination learning of children. Monographs of the Society for Research in Child Development, 1963, 28, 53-68.

Staats, A. W. A case in and strategy for the extension of learning principles to the problems of human behavior. In A. W. Staats (Ed.), Human learning. New York: Holt, Rinehart, & Winston, 1964.

Staats, A. W. Learning, language, and cognition. New York: Holt, Rinehart, & Winston, 1968.

Staats, A. W., & Staats, C. K. A comparison of the development of speech and reading behaviors with implications for research. Child Development, 1962, 33, 831-846.

Staats, A. W., & Staats, C. K. Complex human behavior. New York: Holt, Rinehart, & Winston, 1963.

Stevens, K. M., & Halle, M. Remarks on analysis by synthesis and distinctive features. In W. Wathen-Dunn (Ed.), Models for perception of speech and visual forms. Cambridge, Mass.: M.I.T. Press, 1967.

Strickland, R. G. The language of elementary-school children: Its relationship to the language of reading textbooks and the quality of reading of selected children. Bulletin No. 38. Bloomington, Ind.: School of Education, Indiana University, 1962.

Thorpe, W. H. Animal vocalization and communication. In F. L. Darley (Ed.), Brain mechanisms underlying speech and language. New York: Grune & Stratton, 1967.

Time. Programmed poetry. February 22, 1971, p. 77.

Trabasso, T. Reasoning and the processing of negative information. Invited address at the meeting of Division 3 of the American Psychological Association, Miami Beach, Florida, September, 1970.

Trabasso, T., Rollins, H., & Shaughnessy, E. Storage and verification stages in processing concepts. Princeton, N. J.: Princeton University, 1970.

Turner, E., & Rommetveit, R. Focus of attention in recall of active and passive sentences. Journal of Verbal Learning and Verbal Behavior, 1967, 7, 543-548.

Von Bonin, C. Archtectonics of the precentral motor cortex. In P. C. Bucy (Ed.), The precentral motor cortex. Urbana: University of Illinois Press, 1949.

Vygotsky, L. Thought and language. Cambridge, Mass.: M.I.T. Press, 1962.

Warren, R. M., & Gregory, R. L. An auditory analogue of the visual reversible figure. American Journal of Psychology, 1958, 71, 612-613.

Watson, J. B. Psychology as the behaviorist views it. Psychological Review, 1913, 20, 158-177.

Weaver, W. W., & Kingston, A. J. Modeling the effects of oral language upon reading language: A working paper. Paper presented at meeting of Literature Search Conference, New Brunswick, N. J., February, 1971.

Weiss, H. H., & Born, B. Speech training or language acquisition. American Journal of Orthopsychiatry, 1967, 37, 49-55.

Werner, H. The concept of development from a comparative and organismic point of view. In D. B. Harris (Ed.), The concept of development. Minneapolis: Jones Press, 1967.

Werner, H., & Kaplan, B. Symbol formation: An organismic-developmental approach to language and the expression of thought. New York: Wiley, 1963.

Whitaker, H. A. On the representation of language in the human brain: Problems in the neurology of language and the linguistic analysis of aphasia. Working papers in phonetics, No. 12, University of California, Los Angeles, 1969.

Whitaker, H. A model for neurolinguistics. Colchester, England: University of Essex, Language Center, 1970.

Wickelgren, W. A. Distinctive features and errors in short-term memory for English vowels. Journal of the Acoustical Society of America, 1965, 38, 583-588.

Wickelgren, W. A. Distinctive features and errors in short-term memory for English consonants. Journal of the Acoustical Society of America, 1966, 39, 388-397.

Yngve, V. A model and an hypothesis for language structure. Proceedings of the American Philosophical Society, 1960, 104, 444-466.

Yngve, V. The depth hypothesis. In R. Jakobson (Ed.), Structure of language and its mathematical aspect. Providence, R. I.: American Mathematical Society, 1961. Pp. 130-138.

Zedler, E. Y. Development of competencies for the teaching of reading to children who have not learned under conventional procedures. In E. O. Calkin (Ed.), Monograph No. 11, National Institute for Neurological Diseases and Stroke, 1970.

IMPLICATIONS OF LANGUAGE SOCIALIZATION FOR READING MODELS AND FOR LEARNING TO READ

Doris R. Entwisle

The Johns Hopkins University

INTRODUCTION

Builders of learning models have given little explicit attention to representing group differences within models for learning because they have focused on "relationships which are believed to be common to all members of a species . . . and they nearly always present theoretical functions which are assumed to hold for homogeneous populations of organisms [Estes, 1970, p. 3]." Their assumption of homogeneous populations, made for simplicity, is seldom reexamined. It is no wonder, then, that models concerned with specific kinds of learning, such as learning to read, have fallen into the same pattern and that these models also attend very little to variation among groups of learners.

A modest number of models have been formulated to help in understanding the complex behavior of reading; some are process models based on psycholinguistic or neurological theory, while others fall under the rubric of a logical organization of skills or processes for teaching purposes (Singer, 1970). Whether models deal with part of the reading process or are meant to be more comprehensive, without exception they aim at the explication of reading as an activity of a single person. This focus has two implications. First, it has tended to make both model builders and reading instructors ignore the group variation mentioned above. Second, it bypasses the social components of the act of reading and the frequent social context of the reading act. A reader attempts to comprehend a printed message, a message produced by another human being. This interaction of a reader with the printed page is reminiscent of direct interaction between the two members of a dyad where one, the reader, entirely governs the pace of the interaction and where the number of cues may be fewer than in conversational interaction or even overwhelmingly richer. Reading can be viewed as social communication where one person, the author, presents a verbal message for another person, the reader, to decode without the contextual supports of face-to-face encounters. A further social component of the reading act for the young child exists in the

actions and reactions of a teacher, who may be present often in the early stages of learning to read. Only recently has notice been taken of specific interpersonal events occurring as the child engages in communication, either written or oral.

The first section of this paper will consider these two strands: the need for explicit recognition of group differences and the need for explicit recognition of social contexts in models of the reading process and in reading instruction. Special attention will be paid to the sociological determinants of language differences among groups (ethnic membership, rural residence, social class, and the like). Insofar as they are pertinent, sociolinguistic development and socialization of language behavior will be considered. In later sections of the paper, specific relations between group differences and reading models will be pointed up, and some suggestions derived from sociological notions will be made for altering reading instruction.

GROUP DIFFERENCES

Whereas perceptual processes in reading--quality of the retinal image, physiological transduction of radiant energy to nervous energy, short-term iconic storage, and other neurophysiological processes--may vary little from one group of persons to another and a thorough understanding of these processes in even a single person may form a solid basis for understanding these processes in most human beings, it may be unwise to assume that other parts of the process--what is attended to, what meanings are ascribed to various perceptual images, how learning to read may be fostered by teachers, and so on--are the same from one human group to another. There may, in fact, be large interactions between variables like what is attended to and group characteristics like social class.

To enlarge a little on a major point of this paper--that group differences need to be considered in structuring models--I remind the reader that models of the reading process or of reading instruction may show "conceptual ability" or "mental age" identified in a block diagram but the relationships between this block in the diagram and other blocks are left unspecified. Thus no model, so far as I know, links "conceptual ability" to the processing of feedback information obtained during the act of reading when the reader presumably matches his decoded information with language data he has previously stored. If the correspondence between decoded and stored information varies from one group of individuals to the next (for example, if the set of rules embodied in one speaker's dialect is not the same as those for the majority dialect), current reading models do not take account of this. Nor in considering types of reading instruction, phonics

methods versus whole-word methods, for instance, is notice taken of factors which predispose some groups of children (middle class) to engage actively in formulating and testing hypotheses and which predispose other groups of children (lower class) to rely more on rote memory and appeals to authority. Phonics instruction, at least on the surface, appears to be more consistent with the cognitive styles of middle-class children. Evidence is accumulating that socio-economic status is a more crucial influence on reading performance than IQ (see Lambert, 1970; Lundsteen & Fruchter, 1969). The cluster of variables representing SES is now beginning to be seen not as an amplifier or attenuator of IQ so much as a filter, an overriding determinant of cognitive habits and styles that modulates all the information-processing activities of developing human beings.

Those parts of visual perception that depend on neurophysiological events and on spatial relationships of objects and symbols may differ little from one social group to another in English-speaking countries, although the problems here have not yet been adequately researched. (Later in this paper, a few studies are reviewed that suggest some variation in visual and auditory perception associated with social class.) But if one trend stands out in recent research in perception, it is that of seeing perception as an active process where the percept is shaped by the perceiver. What meanings are perceived, indeed even what stimuli are selected to be perceived, are culturally shaped, perhaps to a considerable degree. Gibson (1950) emphasizes that the visual world is endowed by the human perceiver with attributes the visual field does not possess, properties of uprightness, of stability, and of unboundedness. Even though one's head moves, one does not see the surround as departing from perpendicularity. Similarly, in learning to read, the reader learns to endow the message coded on the printed page with qualities that the actual image does not possess. Learning to read depends upon a whole series of complex learnings about social roles, oral communication skills, problem-solving strategies, the nature of the world, and means-ends relationships.

Before considering the separate facets of cognitive development that seem to differ most with social class or ethnic group, or both, and that probably affect reading and reading instruction, I will review briefly recent research in the United States and Great Britain on the socialization of language behavior.

Research in Sociolinguistic Development

It has been known since the '30's (Smith, 1935) that children's language varies from one social class to another. The association between social stratification and language

development has been repeatedly redocumented up to the present (Bee, Van Egeren, Streissguth, Nyman, & Leckie, 1969; Davis, 1948; Hess & Shipman, 1965; Hess, Shipman, Brophy, & Bear, 1968, 1969; Loban, 1963; McCarthy, 1946). Before the last decade, however, research in developmental sociolinguistics was sporadic, sparse, nonsystematic, and for the most part atheoretical. Bernstein's efforts to fashion a sociolinguistic theory emphasizing language socialization and educability, and the efforts by him and others to validate the theory empirically have changed the picture (Bernstein, 1960, 1962, 1967, 1970a, 1970b, 1971; Bernstein & Henderson, 1969; Lawton, 1968).

The decade of the '60's saw a large number of studies triggered by Bernstein's hypotheses both here and abroad. See, for example, Bee et al. (1969), Bernstein (1960, 1962), Hawkins (1969), Hess and Shipman (1965), Lawton (1968), Rackstraw and Robinson (1967), and Robinson (1965). Various facets of Bernstein's theory have been tested and empirical work has been successfully replicated in some cases. Lately, in the United States, sociolinguists have paid much attention to nonstandard dialects, in part because they disagree with Bernstein's hypotheses. Considerable work remains to be done, however, especially on the parts of the theory linking social roles to linguistic development (Cazden, 1968). As will be made clear shortly, Bernstein emphasizes differences in use of language--the working-class person uses a restricted rather than an elaborated code. Others have, perhaps too hastily, interpreted "difference" as "deficit," and assumed or looked for linguistic and perhaps cognitive deficits in less privileged social groups.

I will now review briefly Bernstein's position, at least that part of it that I see most relevant for the reading process and for reading instruction. I hope that this will point up the implications of Bernstein's theory for reading models, even though it is a perennial problem to interpret work like Bernstein's without distorting it. The theory has been elaborated continuously over the last decade and its most recent and comprehensive statement is contained in Bernstein (1970b).

Much of Bernstein's early theorizing was not empirically based and even avoided empirical considerations. Numerous empirical studies spawned by his theorizing have subsequently supported his intuitions, however. The general theory has wider concerns than language and social class; socialization practices are examined to permit the tracing out of the origins of linguistic behaviors. Actual socialization mechanisms and strategies are described so the theory is much more than a rationale to explain social-class differences. Bernstein makes a serious attempt to tie language development to the internalization of social roles within the family.

Bernstein, a sociologist, views relationships between social class and linguistic codes as derived from the interplay of the role systems and linguistic codes. He contrasts person-oriented and positional families; the latter have closed communication systems. More role discretion (a greater range of alternatives) is available in person-oriented families. The child makes his role. As he makes his role, he learns to cope with ambiguity and ambivalence. Person-oriented families very early in a child's life sensitize him toward, and promote, his language development so they may apply their favored modes of control. It is important to notice (Turner & Pickvance, 1970) that orientation toward codes may be independent of the psychology of the child--independent of his native ability.

Bernstein sees socialization within the family proceeding within a critical set of interrelated contexts: (1) regulative, (2) instructional, (3) imaginative and innovative, and (4) interpersonal, where the child is made aware of his own and others' affectional states. Families make palpable to the child these four critical orderings of culture through the linguistic realizations families provide of these four contexts.

Bernstein assumes that social settings generate particular forms of communication which shape the intellectual orientation of the child. Different forms of social relations generate different speech systems. Working-class families emphasize the communal over the individual, the concrete over the abstract, positional over personalized forms of social control, substance rather than exploration of motives and intentions. The cultural discontinuity experienced by the working-class child when he enters school stems from two radically different systems of communication: the restricted code of the working class he has so far been exposed to at home, and the elaborated code he now hears from his middle-class teachers. Bernstein sees these divergent communication systems as leading to a general diminution in educability. Although he does not specifically mention reading, reading problems and reading failures may be a large component of the educability diminution.

For us, the most prominent terms in Bernstein's theory are "restricted code" and "elaborated code." Bernstein (1962) defines them ". . . on a linguistic level, in terms of the probability of predicting for any one speaker which structural elements will be used to organize meanings." Speakers of an elaborated code select from a relatively extensive range of alternatives. Bernstein sees a restricted code arising from social relationships based on a common set of closely shared identifications where the code reinforces the form of the social relationship by restricting the verbal signaling of individual experience. The range of expression is narrowed.

I see a number of direct implications of Bernstein's theory for reading although I have not seen such implications drawn by Bernstein or his colleagues. Use of an elaborated code could imply that, if it is difficult to predict which of many syntactic alternatives a speaker will take to organize meanings (elaborated code), there is pressure toward cognitive flexibility. This would be advantageous under almost any reading model. Another perspective suggested by the theory is that of viewing reading along a continuum of social solidarity; the continuum is one based on the range of common assumptions, shared identifications, and shared expectations. Having already moved to the right along this continuum,

Oral Discourse (Restricted Code)	Oral Discourse (Elaborated Code)	Symbolic Discourse (Reading)
High Solidarity		Low Solidarity

the middle-class child can be pushed more easily still further toward the right and eventually interact verbally (read) without any social supports except those on the printed page.

Reading, by definition, is apprehending a printed message without other contextual supports. From the page, the child must extract enough information to reconstruct the message, using only linguistic cues. A child who speaks a restricted code, in Bernstein's sense, is conditioned to particularistic speech and may rely heavily upon extralinguistic information in his everyday communication behavior. He thus may have acquired a cognitive style for acts of communication that is maladaptive for reading.

Space does not allow an extensive summary of the research findings concerning elaborated and restricted codes --they would now fill a book--but a few outstanding facts about codes that may pertain to reading can be cited.

1. Social-class differences in language. A number of studies suggest that social-class differences in language are congruent with Bernstein's descriptions of codes, such things as: speech differences in predictability, self-corrections, the use of anaphoric or exophoric pronouns, simpler or shorter sentences, vocabulary range, use of subordination, the adjective/verb quotient, self-reference, expression of uncertainty, syntactic complexity, and use of qualifications (Bee et al., 1969; Brent & Katz, 1967; Cazden, 1966; Deutsch, 1965; Gussow, 1965; Hawkins, 1969; Hess & Shipman, 1965; Loban, 1963; Osser, 1969; Osser & Harvey, 1969; Rackstraw & Robinson, 1967; Raph, 1965; Robinson, 1965; Shriner, 1969; Turner & Pickvance, 1970; Williams & Naremore, 1967, 1969). The question raised by Cazden (1968) and others about whether use of a restricted code indicates limited ability or merely reflects situational press--a working-class child may have more language competence than his performance on a particular test indicates because he

is relatively unmotivated or ill at ease--is of great importance for theory development but perhaps of less importance for reading. If a child typically responds with a restricted code in settings resembling those of the school, he may be severely handicapped in learning to read even though he is potentially capable of code-switching and of using an elaborated code.

2. British versus American data. Much of the evidence on grammatical features and hesitation phenomena relevant to Bernstein's codes is drawn from English data. American research most closely linked to Bernstein's notions (Hess, Bee, and their colleagues) has included some work on identifying codes, but mainly in relation to maternal socialization practices. Although there seem to be features in the speech of lower-class American groups that resemble features of a "restricted code"--a high incidence of personal pronouns, decreased syntactic complexity, and so on--it is hard to know how far findings about codes should be expected to generalize across the Atlantic.

Features of working-class and middle-class British speech would not necessarily be expected in the speech of the lower-class black ghetto resident or the upper-class white southerner, respectively. On the other hand, there may be similarities between person-oriented and positional families and the learning of roles that shape speech in both England and the United States. The fruitfulness of Bernstein's notions for analyzing American speech may lie in the general sociological approach and in suggestions for strategies of linguistic analysis rather than in the replication of specific empirical findings.

Some evidence of class differences in American speech exists, however,--particularly differences that relate to cognitive style. The work of Hess's group and Bee's group has already been mentioned. Loban (1963) speaks directly to this point. He finds that low scorers on his measure of language complexity include more children of low socioeconomic status. He notes that low scorers' control over language does not increase with age as fast as that of high scorers. Loban concludes:

> Nothing in the present research with subjects on the West Coast of the United States contraverts Bernstein's findings or conclusions--subjects from the least-favored socioeconomic categories [could] find themselves at a disadvantage in schools where the verbal linguistic skills of the middle class prevail, find[ing] themselves increasingly ill at ease and self conscious to the point of avoiding oral performance. Such avoidance could, in turn, progressively affect performance in the related activities of reading.

Research of Brent and Katz (1967), Cazden (1966), Deutsch (1965), Gussow (1965), Raph (1965), Shriner (1969), Williams and Naremore (1967), and others is consistent with Loban's. Reduced control of language together with avoidance of oral performance could greatly hamper the beginning reader.

3. Socialization practices. Bernstein's theorizing has stimulated attempts in the United States to conceptualize more carefully the linguistic components of social class and to specify precisely those socialization behaviors that lead to presumed cognitive differences. Work at the University of Chicago shows a close relation between parents' attitudes toward language, maternal language behaviors, and children's cognitive performance (Hess & Shipman, 1965). If children are taught to formulate and test hypotheses, to identify solutions tentatively, to expect and to deal with uncertainty, to respond to verbal rewards--to name a few of the cognitive strategies apparently fostered by the middle-class parent--such children should be in a more favorable position to start learning how to decode written messages. As will be seen in the next section, the relation between socialization practices and cognitive development has come to be a dominant theme in recent American research.

Differences in Cognitive Skills

The evidence on intelligence-test differences between social class and ethnic groups is too well known and too extensive to be documented here, but it is worth noting that this concern is not a recent one. Of potentially greater relevance is the evidence of ethnic differences in the organization of spatial and verbal abilities (Lesser, Fifer, & Clark, 1965). Social-class differences are found on the recent and more specialized tests of language functioning like the Illinois Test of Psycholinguistic Ability (see Barritt, Semmel, & Weener, 1968; Cazden, 1969; Karnes, 1969). The ITPA and reading tests correlate, of course, but exactly how language function affects reading behavior is not known, so what language-test differences specifically imply for reading is unknown.

There appear to be radical differences among various sectors of the population in the development of multi-dialectal skills, in the control of "elaborated" speech, and in the use of verbal mediators to store information (Ervin, 1964). Lately, there has been interest in analytic and integrative scanning and in other cognitive-style processes in relation to social-class variables. All of these skills are, or could be, directly related to reading success. The process of learning to read depends on cognitive strategies and types of interpersonal communication that may be socialized differently in different social groups. Absence of social

deprivation is seen as important if adequate pictorial, analytic, and verbal abstract functioning are to develop (Hess & Shipman, 1965; Sigel, Herman, & Hanesia, 1967) but what must be present, what is social privilege in terms of cognitive development, is problematic.

What are the cause-and-effect relationships between the home environment and cognitive development? Precise answers are mostly unknown. Variables under study include the amount and variety of stimulation in the home, parental patterns of reinforcement including feedback, characteristics of parents' language, and other characteristics of parents. Present research is often oriented toward "weaknesses" in lower class, disadvantaged, or poverty-level homes. A very few studies (see Stolz & Legum, 1967) try to relate school socialization to linguistic behavior. More work of this kind is called for.

Early socialization provides a values code as well as a language code. Affective and cognitive socialization go together. Both codes may be important determiners of success in reading. The lower-class child reared to value immediate material rewards is less willing to delay gratification and probably also less apt to be gratified by the kinds of rewards usually attached to reading success. Rewards like verbal reinforcements and positive social relationships with middle-class adults may be valueless to such children. Traditional working-class socialization often sees education as irrelevant to life. Reading may be viewed as a "waste of time" compared to activities involving physical action.

I see numerous examples of research on child-rearing practices that affect particular cognitive skills of children which may serve to prepare or hinder these children as they start to learn to read. A number of cognitive skills presumed to be important will be discussed briefly below. Most of this research is not concerned directly with reading, but as I will suggest, the link to behaviors facilitating reading is one that seems natural.

As far as general "readiness" is concerned, readiness scores vary for preschool children and can be used to predict potential dropouts (Jensen, 1968). Teachers make much of readiness and feel that parents "should talk and listen to the child" to foster readiness (Gallup International, 1969a). Being read to regularly from the age of two on is a feature that distinguishes between successful and unsuccessful first-graders (Gallup International, 1969b). A study of children scoring high and low on language subtests of the California Test of Mental Maturity (Milner, 1951) suggested that high scorers were read to on a regular basis by their parents, had more books available, and were taken more places by their parents. Of perhaps more interest is that high scorers

participated in conversations at mealtimes whereas low scorers were actively discouraged from doing so. (Unfortunately, in these studies several other variables are confounded. For instance, in Milner's study social class is confounded with score level and no mention is made of IQ. For this reason it is impossible to state unequivocally that it is the verbal socialization practices rather than some other variable or variables that may lead to superior reading readiness.) Also, in grades 3 and 4, Rankin (1967) finds that high-achieving inner-city children, compared to low-achieving children of this type, have parents who encourage their children to read to them and who read themselves at home.

Below, a number of cognitive-style factors are discussed. The documentation of these factors is not intended to be exhaustive. Rather, the intent is to point up some specific components of socialization practices that could require some alteration or amplification of present reading models.

Perception

"Differences in perception' can be broadly interpreted as differences in what is attended to, in what cognitive dimensions are utilized. These broader kinds of perceptual differences are discussed as facets of cognitive style. A narrower range of perceptual differences--differences in auditory perception or in visual perception intimately linked with the decoding of printed text to pronounced phonemes--will be discussed here.

Other than those concerned with visual defects and disease, I have seen few reports of differences in visual perception associated with social class. Exceptions are a study of Covington (1962) and an early study by Bruner and Goodman (1947). In Covington's study, on a pretest of perceptual discrimination of upper-status and lower-status kindergartners where children matched a standard form by using a set of three other similar forms, upper-status children were near their maximal performance at first exposure. Lower-status children showed a marked benefit from experience providing more familiarity with standard forms. Bruner and Goodman found that children from a slum settlement house overestimate the size of valuable coins (quarters, half dollars) more than children from "fairly prosperous homes."

Insofar as anyone knows, the development of letter perception studied by Eleanor Gibson and her associates (Gibson, 1969) is the same across subcultural groups or social-class levels, although this may warrant some checking.

Differences in auditory perception associated with social class are reported for some subtests of the ITPA--

auditory decoding, auditory-vocal associations, auditory-vocal automatic, as reported by Barritt, Semmel, and Weener (1968); vocal encoding, auditory-vocal automatic, auditory-vocal associations, as reported by Karnes (1969); auditory associations, grammatical closure and auditory reception in the Westinghouse study, cited by Cazden (1970). These test differences, however, are difficult to interpret in view of the work of Baratz (1969), showing that the errors black children make in repeating standard English sentences are related to the differences between Negro nonstandard speech and standard English (third-person-singular verb inflections, and the like). Children who speak only standard English make errors in repeating black nonstandard English sentences read to them. The point is that ability to make certain auditory discriminations apparently depends on the kinds of discriminations one is used to making that are important for signaling meanings. If a student is tested on discriminations outside his normal dialect, his competence may be assessed unfairly. It is like asking an American adult to discriminate quickly among Japanese ideographs.

Test differences need not imply a general failure to make auditory discriminations of the kind postulated by Cynthia Deutsch (1964) or by Klaus and Gray (1968), who speculate that living conditions in slums provide noisy environments, so children's auditory discrimination abilities are generally underdeveloped. Klaus and Gray say that lower-class homes lack spatial and temporal organization: "The television set booms all day. . . . Rather than responding to stimulation selectively, the child learns to disregard it--to tune it out, so to speak. . . ." Very specific failures to make auditory discriminations on tests cannot say much about general auditory perception.

Skills of articulation and phonemic discrimination need study where dialect differences are controlled. Studies by McArdle (1965) and by Clark and Richards (1966) do not control on dialect. In a nicely designed study of auditory reassembly abilities of black and white children living in Michigan, black first-graders were significantly below white first-graders, but by third grade, if anything, the difference is reversed (Beasley & Dickie, 1971). Blank (1968), studying Israeli children who were retarded in reading, found that single words are perceived accurately, but that when words, correctly perceived in isolation, were presented in pairs, the retarded readers tended to hear them as the same. Blank believes that an attentional or set factor, rather than a strictly perceptual factor, related to auditory discrimination, distinguishes normal from retarded readers. Related to this is Krauss and Rotter's (1968) observation that low-status children are inferior to middle-status children as listeners (decoders of labels previously provided by other children of low status or middle status). The lowered ability to decode suggests the kind of cognitive problems that could contribute

to reading difficulties of lower-class children. Their handicaps as listeners are not failures in auditory perception but failures in processing auditory data. This suggests, as was the case for visual perception, that "pure" auditory perceptual ability varies little among groups, but no one really knows.

Affective Factors and Views of the World

Diffuse affective factors, like self-confidence, feelings of ability to control the environment, and hope in the future, are probably of enormous importance in cognitive development. Social and ethnic groups differ greatly in how confident they are of extracting benefits, economic or educational, from their surroundings, and how responsible they personally feel for success or failure. Less diffuse affective factors like the effectiveness of material rewards compared to verbal rewards, the ability to delay gratification, and feelings of hostility toward adults are also important because they govern the conditions of practice. A reward like some free time or a piece of candy may persuade lower-class children to practice spelling, whereas the teacher's smile or the hope of a good mark in a month or two may not. Even such small things as the tone of voice used to deliver instructions has a differential effect--positive intonations work best in giving lower-class kindergarten children instructions whereas middle-class children respond similarly to positive, neutral, or negative tone (Kashinsky & Wiener, 1969). The hostile and defeating attitudes of teachers toward students in ghetto schools, where children rapidly learn that they are expected to fail, is often pointed to as a cause of low achievement among minority-group children (Katz, 1968).

Control beliefs are thought to be especially important. The most widely cited evidence on control beliefs is that in the Coleman report (1966, p. 321):

> It appears that children from advantaged groups assume that the environment will respond if they are able to affect it; children from disadvantaged groups do not make the assumption but in many cases assume that nothing they will do can affect the environment.

Even <u>within</u> one social-class group, control beliefs are related to school performance. Hess's group finds, for example, that the more a mother feels externally controlled when her child is four years old, the more likely her child is to make a poor academic record upon entering school (Hess, 1965).

In spite of what has just been said, however, research linking control beliefs to school performance is not as tidy as a superficial look at the literature might suggest. Most

of the studies of control beliefs do not take IQ into account. The one study where race, SES, and IQ are used as stratifying variables has serious methodological flaws (Battle & Rotter, 1963). "Control beliefs" can easily be translated to "response to one's own IQ." On the average, blacks have lower IQ-test scores, so their lower control beliefs may be a realistic assessment of future likelihoods. In the Coleman report, scores taken as achievement scores would be labeled by most psychologists as IQ scores, so the relation between control beliefs and achievement reported there could be read as a relation between control beliefs and IQ. It is not surprising that children with higher IQ's should feel themselves in more solid command of their own destinies irrespective of social class. Because IQ and social class are strongly correlated, the relation seen as one between control beliefs and social class could just as well be seen as one between control beliefs and IQ.

A number of studies examine more specific control beliefs--the child's estimate of his control over his own educational successes and failures. First, these studies do not seem to be tapping the same variable as those cited above. Control over school-related events need not mirror feelings about generalized control in all sectors of one's life. Second, control beliefs may sample several factors--control over success vs. failure, guilt feelings or anxiety, and others. This variable needs more conceptual clarification, for it is not clear how level of aspiration, the self-concept, self-concept of school ability specifically, self-esteem, and control beliefs interrelate or how they overlap. Third, much more careful analysis and study of factors like IQ in connection with control beliefs is needed.

Despite the state of confusion in this general area, it probably is true that the hidden curriculum of the middle-class home inculcates a general expectancy for success in school and gives practice in those interpersonal skills that help children attain such success. In their preschool years, middle-class children, more often than lower-class children, engage in activities like those of the school. Milner (1951) reports, for example, that lower-class children find very few things to be happy about, whereas middle-class children appreciate the time their parents spend reading to them and taking them places. Middle-class parents more often make positive comments when a child is trying to solve a problem (Bee et al., 1970), and a number of British studies suggest that, compared with lower-class mothers, middle-class mothers of five-year-olds answer questions in a more informative way. They recognize the educational potential of toys and generally favor language as a means of conveying information about elements of the child's world.

The child's feelings of control and his generalized expectation for success may be especially important in reading.

Middle-class parents, acutely aware of the importance of reading for later academic success, probably tend to notice and reward any "academic" activities of a preschool child. Precise data on this are needed. Such parents are also more capable of performing environmental maneuvers that may enhance reading success. For instance, boys born late in the calendar year (November, December) are often advised to delay school entrance to the following year. Such advice, even if given equally often to the less advantaged, may be difficult to follow if the mother must be employed outside the home and so needs the school for baby-sitting. Middle-class parents also have more resources to recognize and correct any early barriers to reading--poor vision, poor hearing, emotional problems, or problems related to readiness and timing. The social-class distribution of physical handicaps that could interfere with early reading success is well known (Eisenberg, 1970). Physical ailments left uncorrected for even a short time are probably expensive in self-confidence and self-esteem.

Problem-Solving Behavior

There are apparently large social-class and ethnic differences in problem-solving strategies, such things as generating and testing hypotheses, willingness to defer solution, ability to verbalize crucial elements in a problem, and general tolerance of uncertainty. Even the tendency to describe objects in part or as a whole seems class related (Heider, Cazden, & Brown, 1968; Shriner, 1969). Bruner (1970) sees crucial differences among groups in goal-seeking patterns and goal-directedness. In several studies of verbal interaction between mothers and their children as mothers attempt to guide the children in solving problems, middle-class mothers, compared to lower-class mothers, take more actions that will help their children to become successful problem-solvers (Bee et al., 1969; Cook, 1969; Henderson, 1969; Hess & Shipman, 1965; Rackstraw & Robinson, 1967). Bee notes that the middle-class mother allows her child to work at his own pace, offering general structuring suggestions on how to search for a problem's solution and telling the child what he is doing that is correct. The lower-class mother, by contrast, makes more controlling and disapproving comments, and makes more highly specific suggestions that do not emphasize basic problem-solving strategies. Although Bee does not note this, concept-formation studies generally show that positive instances are more helpful than negative instances--if a child must recognize a specific color as part of solving a problem, it is more helpful to be told "It is red" than "It is not green," for the second answer still leaves many alternatives to be tested. Thus, when the middle-class mother emphasizes what is correct, she effectively blocks off a number of alternatives whose exploration would be fruitless. Hess and Shipman (1965) note that lower-class mothers do not

permit their children enough time to formulate alternative hypotheses. Middle-class mothers show more tentativeness and see more alternatives to explain behavior (Cook, 1969). Middle-class mothers are more receptive and responsive to their children's questions, tend to evade questions less, and to give more accurate and more informative answers (Henderson, 1969; Rackstraw & Robinson, 1967).

A rationale to explain class-related differences in maternal socialization behaviors is proposed by Klaus and Gray (1968). The lower-class mother discourages exploration and active problem solving because she is apt to reinforce those child behaviors--withdrawing and passive behaviors--that make her life endurable over the short run. How so? There is little space for children to play, outside or inside. Passive TV watching can root several children to one spot where quarreling among them may be cut down and where disarrangement and destruction of the premises is also held down. If the mother works and does not have adequate supervision at home for her children, she may favor withdrawing and passive behaviors even more. These specific reasons that I see for encouraging passivity do not run counter to any convictions held by the lower-class mother that active play, overcoming certain kinds of environmental challenges, some kinds of "messy" toys, or social play may enhance their children's cognitive development. Middle-class mothers, by contrast, see play and activity as means of fostering children's development (Bernstein, 1967; Jones, 1966). Over several cultures, mothers' immediate-reactive techniques, treating the child so as to reduce bother at the moment, are associated with mothers' low control beliefs about ability to rear a child of the desired type (Graves, 1970).

The task of learning to read is in many ways a learning of effective problem-solving strategies, so social-class differences in the way problems are seen and structured could bear heavily on reading success. The child's problem is to learn how to decode messages. If, first of all, he <u>expects</u> success and if he has the intent of persisting until he does succeed, no one would doubt that his chances of success are improved. In decoding a message, the child makes use of many kinds of cues--semantic, contextual, grammatical, sociolinguistic--so that it is profitable to formulate and test hypotheses about the message. If he finds one set of cues in conflict with another, he may wish to revise his hypothesis about the message. When the situation is structured as a probabilistic one--"this message is more likely to be right than another one" and the child can tolerate a certain amount of ambiguity as various hypotheses are tested--the child improves his chances of converging upon the "correct" message. At least when the child is cognitively attuned to uncertainty, he comes with the expectation that alternative behaviors are "good" and not "wrong." If he has been

encouraged to explore his environment, he may search all over the page or mentally generate and reject possibilities to "explain" the written symbols.

Hypothesis testing and guessing may often be reinforced for the beginning reader. English is estimated to be about 50 percent redundant (Miller, 1951). Group differences in willingness to guess have been documented; Hochberg and Geffner (1969) find that white subjects use a guessing strategy significantly more often than blacks in a task requiring them to match patterns of light bulbs in a matrix. Group differences would also be predicted on the basis of Loban's (1963) finding that lower-status subjects appear to be less flexible in their thinking, and his finding that uncertainty and tentativeness are more often characteristic of middle-class than lower-class speech. When children try to identify environmental sounds (typewriters clacking, telephones ringing, and such) nondisadvantaged subjects appear to be more capable than the disadvantaged in coping with stimulus situations by

> being able to formulate more than one alternative interpretation of what they perceived . . . [having] a greater ability to emerge with an interpretation as a meaningful whole . . . [integrating] the entire stimulus situation into a meaningful response [Hochberg & Geffner, 1969].

Taking this evidence altogether, what one sees is greater cognitive flexibility in the middle-class child--he concentrates on details when necessary, but tries and retries solutions until a satisfactory and integrative solution is found. This is exactly what reading requires.

Cognitive Implications of Code Differences

The best-known part of Bernstein's theory is that part dealing with "restricted" and "elaborated" codes and this aspect of his theory has been briefly touched upon earlier in relation to linguistic development. Bernstein feels that forms of socialization orient the child toward speech codes that are relatively context-tied or context-independent, as already discussed. He has insisted that a restricted code, although more characteristic of working-class than middle-class speakers, is in no sense deficient; it is merely different. Kinds of specific differences were enumerated earlier. Bruner (1970) agrees, stating that there is little doubt that children from one social class "move toward a program of linguistic analysis-and-synthesis while others move toward a more concrete, image-bound, often metaphoric form of reckoning and reasoning." He suggests that middle-class children's _use_ of language is as an instrument of analysis and synthesis in problem-solving and that these children _decontextualize_ language; for them the message is self-sufficient.

Bruner (1970), Cazden (1970), and others place great emphasis on the distinction between language and the use of language, and they concur with Bernstein in his insistence on the restricted code's not being deficient. They feel that the critical issue is use in a variety of situations, i.e., sociolinguistics rather than linguistic development *per se*. The acquisition of ordinary or extraordinary uses of language is an accomplishment different from the acquisition of grammar. Although the topic is too large to treat in this paper, much of the evidence documenting code differences may be criticized on grounds of confounding with possible situational factors. Situation is an important determinant of the complexity or type of language emitted (Cazden, 1970; Kessel, 1970; Lawton, 1968; Mohan, 1970; Shriner, 1969; Smith, 1935; Strandberg, 1969; Williams, 1970). To give a single example, in Bernstein's early studies of working-class and middle-class English boys, a language sample is obtained by asking the boys to discuss capital punishment. This topic may be much more natural for middle-class boys than for working-class boys to discuss. Even the process of "discussing" may be more natural to the middle-class boys. The adults monitoring the discussions are middle class, potentially inhibiting the lower-class boys. A mismatch between social class of experimenters and respondents is thought to have important consequences for performance (Entwisle, 1968; Entwisle & Webster, 1971).

As one tries to link language performance to educability and to reading achievement, the pervasive deficit-difference controversy may be somewhat irrelevant, however. Lower-class children mostly use a restricted code--simpler sentences, a restricted grammatical range, fewer subordinated clauses, more exophoric pronouns, fewer expressions of uncertainty, fewer self-corrections, and fewer abstract words. They often do not switch codes in situations where they deal with middle-class persons (as in school). Their potential competence in using and understanding elaborated code expressions is not often displayed. It may thus atrophy from lack of practice, and verbal interaction and communication in the school may not fully engage lower-class children. Much evidence suggests that perception of words is related to frequency--familiar words are perceived faster and more accurately than unfamiliar words. One would expect these findings to generalize to larger chunks of language--sentences with familiar constructions probably can be decoded more rapidly than sentences embodying less familiar constructions. If lower-class children are being exposed and are exposing themselves to language of the restricted-code variety, they may find it more difficult or slower to decode messages in elaborated codes even though they are theoretically capable of doing so. Some direct evidence for this is contained in Robinson's (1965a) study using a cloze procedure. In filling in deletions in oral utterances or letters produced by members of the working class and middle class, middle-class boys used a wider range of words.

There is a subtle affective consequence of restricted code for reading instruction. This is the tendency of working-class children to take certain role relationships for granted in their speech, which results in their assumption of a kind of informality in speaking with teachers that is seen not as a code characteristic, but as a mark of disrespect. A lower-class child may not know the mitigating ways of disagreeing with the teacher which make such disagreement acceptable--Negro children may accuse the teacher of lying whereas the middle-class white child might say "There's another way of looking at it" (Labov, 1969).

"Styles of learning" picked up at home may differ markedly from those introduced in the schoolroom. This may lead to sociolinguistic interference when teacher and student do not recognize these differences as they try to communicate with one another. Therefore, I feel that code differences (or dialect differences to be discussed in another section) must be interpreted very cautiously in trying to relate language and cognition and in trying to gain basic understanding of the acquisition of psycholinguistic and sociolinguistic competence. I feel at the same time that code differences, which reflect use (frequency), may profoundly affect the child's likelihood of getting positive feedback from decoding efforts as he learns to read and his likelihood of getting positive feedback from reading instructors. The whole information-processing operation in lower-class speakers relies more on nonlinguistic cues. This should make reading, which depends almost wholly on linguistic cues, relatively more difficult.

To sum up: the tendency has been to assume that <u>all</u> children possess the same kinds and amounts of cognitive skills (Venezky, Calfee, & Chapman, 1968). Little research has been carried out on the nature of these skills in students of differing backgrounds and ability levels at various stages of training. In particular, little work has been done to clarify the implications of reading models with regard to the kinds or amounts of cognitive skills required--visual and auditory perception, segmentation, long-term and short-term memory load, inductive and deductive inference, and information processing. To this, we can add that almost no work exists on the relation between oral language and reading achievement, although it is known that there <u>is</u> considerable variability in oral language across social or ethnic groups, or both. In the next section I will look at a few representative reading models and suggest where in these models cognitive-style differences may impinge.

READING MODELS AND GROUP DIFFERENCES

To show specifically how group differences in cognitive style, cognitive skills, communication behavior, and

language socialization may affect reading models, I will now consider three current models in detail and indicate where these models might be extended.

Gibson's Model

Gibson (1970) points out that visual perception for large objects and environmental events is different ontogenetically from sequential perception of small symbols, the kind of perception required in reading. The distinction between the two kinds of perception is apparently physiologically based and ecologically adaptive. She states unequivocally, unlike some other model builders, that the vital first stage in reading is learning to communicate by spoken language. This is followed by learning to differentiate graphic symbols, learning to decode letters to sounds, and using progressively higher-order units of structure. Let us consider these four phases in turn.

1. Considerable evidence exists, and has been reviewed above, that communicating by spoken language differs from group to group. Osser (1969) sees the communicative competence of the child embodied in the several rule systems he must learn: (a) formal linguistic rules of his dialect; (b) sociolinguistic rules of his social group; and (c) social-cognitive rules, a kind of analysis of listeners' characteristics. Groups differ in dialect rules and sociolinguistic rules and also in "style" rules, if one might thus name code differences. Some differences are all-or-none, as when a speaker of Negro nonstandard dialect uses a different marker from the majority dialect to indicate the possessive (omitting the "s" entirely). Other differences are in terms of frequency, as when "in" appears more often than "ing" at the ends of words in lower-class American speech, although the latter is not absent entirely. Normal children learn to communicate by speaking, but the language spoken by one group (middle-class) is more often in correspondence with written discourse in reading texts than the spoken language of other groups (black-ghetto dwellers, Mexican-Americans, and others). The formal competence of one group--the ability to express logical relations, nuances of meaning, personal feelings--may be equal to that of another. But as Shuy, Baratz, and others have repeatedly pointed out, one would hardly try to teach English-speaking children to read using a text written in French. Teaching reading to a speaker of a restricted code or a Negro nonstandard dialect with tests written in an elaborated code of standard English may pose the same problem. In fact, the problem may be worse than for the English-French example.

The difficulty of learning a new dialect may be much more severe than one might naively suppose for two reasons. For one thing, the problem is usually not made explicit--the

child makes mistakes but it is not clear to him what his mistakes are or how to correct them. He does not realize that he is learning a "new language." For another thing, when learning materials are highly similar, as in two dialects of the same language, interference is probably at a maximum (Entwisle & Huggins, 1963, 1964). It is probably harder to distinguish codes that are highly similar than to learn a second language. When learning materials are so similar as to be easily confused, both proactive and retroactive inhibition serve to diminish performance. Dialects have in some cases not been completely mapped and group differences in semantic structures have received little attention (Entwisle, 1970), but potentially the kind of interference just described may be why code-switching is so hard. The problem needs study.

2. Group differences in learning to differentiate graphic symbols may not be large but the data on this matter are fragmentary. Cognitive operations (such as learning to process information sequentially, learning how to make exclusions, striving for a single answer, and other activities related to discrimination and stimulus differentiation) apparently differ by social class. Maybe different cues are used by different social groups to draw distinctions; some cues may be more efficient than others. This is a topic requiring research.

3. In learning to decode letters to sounds, there are at least two important ways that group differences might operate: the first, dialect differences where phonology leads sounds coded in the same way to be pronounced differently, and second, dialect differences where syntax leads to violations of the usual grapheme-phoneme correspondences, as, for example, when the black speaker of nonstandard dialect sees "he goes" and reads "he go."

4. In using progressively higher units of structure, again group differences could be important, although little specific information is at hand. It is known that how information is coded greatly affects its processing--an octal coding convention may be convenient for an electronic computer but inconvenient for a human being. Roman numerals are good for some purposes but are unwieldy for subtraction problems. If a person speaks an elaborated code, he probably processes oral language in larger units (longer sentences) or more variable units (sometimes subordinate clauses and sometimes simple declarative sentences) than a speaker who hears mostly restricted code. The elaborated-code speaker may be predisposed to undertake processing of written information in line with his oral processing. Again, nothing much is known about the progressive hierarchization of structural units. Some processing operations are undoubtedly important but not well specified and processing may be modified depending on forecasts.

It seems, then, that every phase of the model proposed by Gibson could be affected by group differences.

Singer's Model

Singer's (1970, p. 156) model, a flowchart showing how components of speed and power of reading are accounted for by specific subskills, is more comprehensive. Some of the same issues can be raised, however, as were raised for Gibson's model. Singer partitions speed of reading into: reasoning in context, auding, phrase perception, and a set of probable factors involving visual-verbal processing.

Reasoning in context must be influenced by problem-solving and goal-seeking styles and strategies, and these differ by groups as was covered in some detail in previous sections of this paper. Such reasoning must also be sensitive to group differences in semantic structure--a word in an unfamiliar context may be extraordinarily difficult (Entwisle, 1970; Entwisle, Grafstein, Kervin, & Rivkin, 1970). If "examine" is known only in medical contexts, it may be difficult for a child to decode it when it appears in a sentence like "The boys examined their consciences." In the same way if exposure to "snake" has always been as a noun, its appearance as a verb ("The river snaked through the valley") may hinder reasoning in context. Reasoning in context presumes some previous familiarity with the type of context being presented.

Auding, Singer's second factor, obviously will be affected by vocabulary differences and differences in word meanings as well as by previous experience with certain distinctive phonological features.

Phrase perception, his third factor, will probably be affected by code differences, by information-processing styles, by phonological differences, and by structural hierarchies.

Geyer's Model

This is a perceptual model (Geyer, 1970, p. 76), and again some of the group differences discussed in the earlier part of this paper impinge on certain elements in the model. For ease in presentation, I have rewritten Geyer's model horizontally and underneath each element listed topics that might be considered best in that portion of his model.

Visual Input →	Coding →	Iconic Storage →	Internal Response →	Verbal Storage →	Verbal Output
process of attention, problem-solving strategy, perceiving distinctions, matching to previously stored auditory inputs (dialect cleavage, code differences)	perhaps influenced by context dependence			errors in storage caused by dialect or code differences, differences in semantics	sociolinguistic rules, choice of code or syntax

One assumes that iconic storage and internal responses are the same for all persons, although there is no evidence on this.

Discussion of Group Differences and Models

There was no particular reason for picking these three models except that they exemplify different types of models and they are all widely known to specialists in the field. What I see neglected by these and other reading models--group differences and the social context of communicative acts--are just those areas which distinguish sociolinguistics from "communication" as usually defined. Sociolinguistics is concerned with code characteristics that relate to communicators' characteristics or to the communication situation rather than with the message or the process of communication alone. As psycholinguists increasingly attend to performance models, sociolinquists insist that these performance models must specify social features (Ervin-Tripp, 1967). Hymes (1970) points to cognitive differences due to differences in speaking as well as cognitive differences attributable to language, and to interference between norms of interaction and interpretation of speech.

Although reading models have not yet formally taken notice of differences among social groups, an increasing number of books and papers is appearing whose aim is to educate teachers on the life style, values, social customs, and socialization practices of various minority groups. (The paperback edited by Thomas D. Horn, Reading for the Disadvantaged: Problems of Linguistically Different Learners, is an example.) Much of what is written about social-class differences in life

style is based more on intuition than on first-hand observation. There is probably a bias on the part of middle-class researchers to see deficiencies. The demographic facts that underlie social stratification--numbers in minority groups, average age, education, occupation, father absence, and so on--are fairly well established. There are, however, only a handful of studies reporting first-hand observations of the facts of lower-class or ghetto life, details of verbal interaction within the family, of actual speech characteristics in everyday situations, or of values and beliefs unedited by the lower-class respondent's desire to look good in the interviewer's eyes or to himself. It is not even clear at this point what variables should be observed.*

When Klaus and Gray (1968), for instance, say that the lower-class home is "spatially and temporally disorganized," this statement is not based on specific data that they cite. The statement may be true, but there seem to be wide differences among middle-class homes in the amount of spatial and temporal disorganization, perhaps differences as wide as those separating the middle and lower classes. Some homes have fathers who travel a great deal; sons who participate in sports in the late afternoons and weekends; daughters who are involved in neighborhood clubs, music lessons, and dates; and mothers who are also busy outside the home, so that it is hard to know whether the lower-class home is more temporally disorganized than the middle-class home. Housekeeping standards vary tremendously, so the amount of spatial disorganization within one social-class level may be as large as that between levels. The fact that there are fewer possessions--fewer books and magazines, less food, less space to accumulate things, fewer shoes and pieces of sports equipment--could make the spatial organization of the lower-class home simpler and more consistent than that of the middle-class home. My only point is that specific data are needed on the life styles

---

*The author, in doing some pilot work prior to beginning a study of verbal interaction in the classroom as affected by classroom aides, had a student recording in an inner-city classroom. After the student left, he paused outside the door of the classroom, out of the teacher's view, while he adjusted his recorder. He noticed that as soon as he left and the teacher no longer thought another adult was listening to her, the tone of her speech and its content changed drastically. She began to berate several children and to comment negatively and unpleasantly. From this, I conclude that having an adult aide in classrooms may not have the effect those of us in ivory towers might suppose; i.e., to increase the total amount of verbal interaction between adults and inner-city children. Rather the main effect may be to constrain the classroom teacher to behave in a decent fashion because another adult is there.

of various social groups, procured in the manner of the anthropologist who observes as a participant. It is often said that lower-class persons see education (and reading) as irrelevant, but it is possible that these views are expressions of defense to ease feelings of stigma and failure stemming from their reduced educability. General advice based on hunches and misinformation will not aid much.

SOCIOLINGUISTICS AND READING

Ideally, sociolinguistic theory would serve as one basis for theories of the reading process and of reading instruction. As noted at the beginning of this paper, reading models see individuals as homogeneous and ignore the social context of the reading act. There is much evidence of group differences in oral competence. Models do not attend explicitly to the relation between oral competence and reading competence and, indeed, little is known about how oral competence specifically affects reading performance.

Reading involves three classes of skills: task skills (general cognitive and language abilities, such as being able to follow instructions and being able to classify objects as the same or different, and the like); oral language skills (articulation, phonemic discrimination, vocabulary, grammatical competence); letter-sound decoding skills (learning first the decoding of single letters to sounds and then using progressively higher units of structure). All these skills are related to sociolinguistics, but the conceptual basis for language education based on sociolinguistic research on child language has yet to be worked out.

Sociolinguists generally have not addressed specific problems of reading--Labov, Shuy, and their associates are exceptions. Rather, most of the sociolinguists' concern has so far been with speech and oral exchanges. Answers to the three basic questions listed below about sociolinguistic development, if available, would provide the information necessary to begin constructing a theory of sociolinguistic development (see Social Science Research Council's Items, June, 1969). Such a theory would be an enormous help to builders of reading models as well.

(1) What features of phonological, grammatical, and semantic development seem to be universal? (2) What are the patterns of development in various social uses of language? How early and in what form do sociolinguistic rules appear? (3) What are the relations between the social organization of the community, values about language and its uses, and how the child is spoken to and rewarded for speaking?

Reading is a language process that depends heavily on other language processes. Using expectancies based on his

knowledge of syntax and semantics, largely gained through speech, the reader guesses a message using only a small number of cues available on the printed page. The cues used may vary from reader to reader and from group to group, and the actual cues may be hard to specify. A recent paper by Schwartz, Sparkman, and Deese (1970) suggests that a preliminary incomplete analysis of linguistic information leads people to judge comprehensibility rather accurately before a complete processing of linguistic information occurs. Such judgments could serve to alert readers to process more or fewer cues, to change rate, to process smaller chunks, and so on.

The child begins very early (Gibson, 1969) to perceive regularities between printed and spoken patterns. Syntactic and semantic patterns are the basis for his graduation to processing of longer units. To show how sparse our basic knowledge of sociolinguistics is, we do not know how structural variability affects reading or whether its careful manipulation would aid or hinder beginning readers (Strickland, 1962). Nor do we know with any exactness, from analysis of errors made by minority-group or lower-class speakers, if the number of regularly heard spoken patterns is reduced, or if so, how this affects beginning readers. There is suggestive evidence (Osser, Wang, & Zaid, 1969) that lower-class black children make more errors in processing oral sentences even when all syntactic errors that could arise from dialect cleavage are removed.

Oral Competence

As already noted, Gibson is more explicit than other model builders about oral competence, for she states that the "vital first stage in reading is learning to communicate by spoken language." Very few children fail to develop enough competence in oral communication to meet the routine needs of family life except those with profound hearing losses and deaf children who have not learned to speak or learned to read with great difficulty. The competence develops without special tutelage, and special tutelage may not help it (Cazden, 1965). The exact process by which this competence is laid down is unknown. People learn to talk like those to whom they are most closely tied in social networks.

Theorists differ in their estimates of the importance of the environmental context for language learning. For a discussion of the current nativist and empiricist positions, see Osser (1970). But the controversy is somewhat irrelevant if one's major concern is language use. How, for example, does the child learn to signal role relationships? Use of language implies a social context for use, if not for structure. The importance of the environment for learning sociolinguistic rules cannot be denied, for even a shared language

does not necessarily imply a shared set of sociolinguistic rules.

All first-graders do not come to school with the same oral competence. So far the components of oral-language maturity which are related to reading success have not been intensively studied. The child must know the language he is going to learn to read, but how knowledge of spoken language interacts with learning to read and what kinds and amounts of competence are desirable before the child undertakes any given task in learning to read are unanswered questions (Carroll, 1970). Loban (1963) shows that children who read and write well by the end of third grade are those who rank high in oral language in the earlier years of school. He says:

> . . . the superiority of the high group in handling signals effectively--their skill at using pitch, stress, and pause-- . . . is impressive. It would be difficult not to conclude that instruction can yet do more than it has with oral language. . . . Competence in the spoken language appears to be a necessary base for competence in reading [p. 88].

Consistent with this is (a) Shire's (1945) finding that first-grade oral reading is predicted better from a combined index of oral-linguistic measures (number of elaborated sentences, average length of response, and total number of words) than from intelligence; (b) Sampson's (1962) finding of a correlation of 0.69 between speech-test scores at age 2-1/2 and reading-comprehension scores at age 8; and (c) Hildreth's (1950) finding that the words in an experiment that are most easily learned are those most often seen or heard previously.

The study indicating most clearly that oral competence is related to reading is that of Strickland (1962). With a careful analysis of oral language of 575 midwestern children (grades 1 to 6), she shows that there is tremendous variety in structures children use and that they use many more structures than are present in the four reading series she selected for analysis. She demonstrates relationships between oral-language complexity (length of sentence, use of subordination and elaboration) and reading competence in grade 6. Her study deals with children who vary little in ethnic background or social class. Oral competence may develop differently in different groups.

Little is known about oral competence at the beginning of school, and little is known about how oral competence changes subsequently, especially about social-class variations in oral development. Lower-class white Anglo children in Texas apparently adopt middle-class speech patterns as they pass from grades 1 to 3 (Stolz & Legum, 1967), but this has not been studied in relation to reading performance. Some

black speakers develop competence in switching from standard to nonstandard codes by high-school age, but again the precise course of this development is not known (Garvey, 1971). People who speak nonstandard dialects tend to use fewer of the optional constructions in their native language and to fill the slots in their constructions from a smaller set of words (Cazden, 1966).

In the past, vocabulary control has been severe in basal readers. Enough has already been written about the inappropriateness of basal readers in terms of the life style of the urban resident--to read in repetitive phrases of a youngster's trivial daily experiences with a dog "Spot" is boring and tedious even for children whose own lives are being described. Strict vocabulary control has crushed spontaneity of interest, and probably also has underestimated the child's oral competence and verbal repertoire (Packer, 1969).

Two other kinds of control, apparently not yet tried, might be worth consideration. One is the "structural sequencing" suggested almost a decade ago by Strickland (1962) and studied by Loban (1963) in investigating language differences by social class. The basic idea is to manage or program the syntax. Ruddell (1963) established that the more similar written-language patterns are to the oral-language patterns of the reader, the higher is the reading comprehension of the child, and later pointed out the need for a comparative longitudinal study of children's reading success using controlled patterns of language structure based on children's oral language (Ruddell, 1965). There is some evidence that reading texts are oversimplified in terms of structure--basal readers widely used in Canada almost never use subordination but children ages 8 to 12 use subordination in from 10 percent to 30 percent of their sentences, with the amount increasing from year to year (Robertson, 1970). Since structural forms develop sequentially and the sequence is apparently invariant even though children develop at different rates, this sequence may provide a more rational basis for calibrating reading material than strict control of the lexicon.

Another kind of monitoring of basal readers that might be worth trying is based on "information-processing difficulty," a composite measure of all the linguistic and social factors that serve to make messages easy or hard to process. As a yardstick, it may surpass any single attribute like vocabulary or syntax sequencing. Adults can and do edit messages they send in terms of their estimates of the information value of the message to listeners, and this ability is apparently acquired gradually starting from a point (nursery school) when no editing occurs (Krauss & Rotter, 1968). Communication accuracy and its several components can be measured (Baldwin & Garvey, 1970).

One rather simple way to take into account structural sequencing, vocabulary knowledge, and perhaps semantic development is to adopt Ashton-Warner's strategy and use materials for reading instruction invented by children themselves. If children generate the material, it has to be consistent with their own language competence.

What little is known of the relation between competence in oral language and reading success suggests that more study of this relationship is desirable. The studies of dialect differences in one sense are studies of oral competence (see the next section) but emphasis has been mostly on dialect cleavage rather than on the basic relation between the two kinds of language competence, speaking and reading. Ways to develop oral proficiency must be brought into the open, rather than hidden in the general curriculum of the middle-class home. The oral competence of various groups is probably not at all the same, even when dialect is constant.

DIALECT DIFFERENCES

The dialect speaker can be viewed as a person with diminished oral competence in the majority dialect. His language differs in systematic and sometimes crucial ways from the language of the majority group and the language of reading texts. The diminution may be slight, as for the dialect of the white resident of the southern United States who drops many final consonants, employs certain lexical variants (y'all, m'am, yeah), and speaks at a slower pace. Or the diminution may be substantial, as for the Hawaiian who speaks pidgin English. In the case of maximally different dialects (i.e., foreign languages such as Chinese or Spanish) clearly school instruction cannot proceed in English either for reading or for substantive areas. It is not clear how "different" a dialect must be before it should be noticed by the school. At what point along the dialect-foreign language continuum does one decide that cleavage is pronounced enough so the "usual" language and reading program of the school is inadequate?

The precise role of dialect differences in learning to read is presently being studied (Cohen, 1966; Goodman, 1965; Labov & Cohen, 1967). Some believe the role is substantial; others believe it is trivial. Gumperz (1970) says: "There is little, if any, experimental evidence that the pronunciations of urban black English actually interfere with the reading process [p. 141]." The disagreement occurs partly because it is hard to isolate dialect as a variable. Dialect differences are often strongly correlated with other crucial variables such as ethnicity and IQ.

Some work indicates that young children can switch easily from one dialect to another (Weener, 1969) or at least

understand both dialects equally well, but more studies point toward the opposite conclusion (Baratz, 1969; Barritt, Semmel, & Weener, 1968; Osser, Wang, & Zaid, 1969; Peisach, 1965). Weener finds that speaker differences are significant only for middle-class children, the ones who would presumably have the least need for dialect switching. Geographic location, intra-city mobility, length of residence in an area, and degree of school integration probably all influence ease of dialect switching or ability to do so, tempering the effect of dialect. Thus, the actual structure of a dialect may be of less importance for dialect switching than the social milieu.

Dialect diversity may affect all levels of linguistic structure--phonological, morphological, and vocabulary selection (Ervin, 1966). There seems little doubt that many American slum children have poor phonemic discrimination, or even different phonemic systems, because of dialect or second-language features. A number of studies show a positive relationship between auditory discrimination and reading achievement (Bond, 1935; Wepman, 1960; Wheeler & Wheeler, 1954). Thus, in spite of the lack (noted earlier in this paper) of well-established relationships between failures in auditory discrimination and social class, it is probably inadvisable to rule out diminished auditory discrimination of particular kinds as a source of reading difficulties for poor children.

Those at the Center for Applied Linguistics have been especially concerned with dialect problems in the teaching of reading, how oral language affects reading, and related educational problems. This work will now be briefly reviewed. Teaching dialect-speaking children to read can proceed by teaching the child standard English before he learns to read, <u>or</u> by teaching the child to read using materials in dialect. There is no consensus on the most desirable approach. Baratz (1970a) recommends that reading be taught first in the vernacular, then in standard English. Venezky (1970) sees the best course of action as the use of materials in standard English that minimize dialect and cultural differences. He does not ignore dialect, however, for he feels that it is essential for the teacher to understand the patterning of the child's speech and for no interference to be allowed with children's attempts to translate from writing to the form of language that they understand best.

The majority recommendation seems to be to teach standard English, using urban-language specialists, "teachers aware of different learning styles," and teachers with strong egalitarian views vis-à-vis subcultures other than their own. The reader can get good overall coverage of the current approach by looking at Aarons, Gordon, & Stewart (1969), Baratz & Shuy (1969), Fasold & Shuy (1970), Gunderson (1970), Shuy (1969), and selected articles in the Annual Georgetown University Roundtable publications.

Whether (a) materials are prepared in dialect, (b) standard English is taught first, or (c) standard materials are designed to minimize conflict with a dialect, knowledge of dialect is necessary. The sociolinguists have begun, by performing contrastive analyses, to pinpoint what seem to be the crucial dialect differences for reading.* They have provided much specific knowledge that is helpful, particularly for urban Negro dialects. Work on Mexican and Puerto Rican dialects derived from Spanish is under way. Some grammatical structures that occur in Negro nonstandard speech do not occur in standard English (use of "be"--"he be busy"). Other features appear which are found in standard English but which are governed by different rules. The formation of the possessive, the plural, the negative, and the past and future tenses in Negro nonstandard dialect differ from standard English. Failures to discriminate certain phonemes that might lead to reading problems have also been identified. Avoiding ambiguities that result from the different grammatical systems of the child's oral language and of the printed page is particularly hard ("she arose" vs. "she is a rose"; "we jump into the water" vs. "we jumped into the water"). There is a large set of words that are homonyms for Negro youngsters but which are not homonyms for most teachers ("pin-pen," "poor-pour").

Clearly analysis of reading errors must go beyond what letters are pronounced correctly (Labov, 1967) for some errors at the abstract-meaning level merit attention. The sentence "I passed the store and read the sign" has a past-tense marker "-ed," which is not pronounced in some Negro dialects. The question is whether the reader notes the past-tense marker. Labov found two groups of Harlem teenagers--none pronounced "-ed" but some pronounced "read" as /red/ and some as /riyd/. Labov would provide intensive drill only for the second group because apparently the past-tense marker for them is not represented in deep structure. This observation suggests how difficult it is in fact to analyze even a single dialect.

The potential difficulty of dealing with dialect in relation to reading should not be underrated. To teach reading in the United States with materials in dialect would require materials to be developed in at least seven dialects: northern urban Negro, southern mountain, Spanish-American, American Indian, Hawaiian pidgin, southern rural (Negro and white), and Acadian English (Venezky, 1970). Separate contrastive analyses for each dialect are required and, of course, teacher-education programs must be geared separately to each dialect. A further difficulty that must be faced is

*Contrastive analyses so far performed are limited to syntax and phonological aspects. Not much notice has been taken of semantic contrasts although Entwisle (1970) points to their possible importance as a source of reading problems.

the lack of a complete description of standard English. Teaching materials so far prepared by the Center for Applied Linguistics for Negro nonstandard dialect are linguistically sophisticated but they have not yet been evaluated in teaching contexts in the United States (Baratz, 1970b). It is hard, therefore, to know at this time whether the enormous effort that would be required to support dialect-based teaching of reading is justified.

Looking at the problem more broadly, one cannot determine exactly what reading materials are in use in the country at large, or what characterizes these materials. Besides the work of the Center for Applied Linguistics, many efforts around the country of all degrees of sophistication and emphasis aim to take account of dialect differences in the teaching of reading. The efforts range from "general" education of teachers about "minority" groups (with the hope that some attitudes or bits of knowledge will filter into the classroom) to programs with high linguistic emphasis. So far as I know, rigorous evaluation of any bi-dialectal teaching programs in the United States remains to be carried out. One beginning reading program designed specifically for "bilingual" pupils has been in use for several years, but Rosen and Ortego (1969) report being "unable to locate published reports of experimental studies with these materials." This situation is typical.

Shuy, Labov, and others keenly appreciate the non-linguistic problems involved in dialect-oriented teaching of reading. They are sensitive to devaluation of the speech of the inner-city or black youngsters by middle-class teachers. Dialect differences in themselves are probably less important than the teachers' ignorance of these differences. Teachers of reading must begin to make the fundamental distinction between a mistake in reading and a difference in pronunciation (Labov, 1969), but even more important, they must come to realize that any dialect has integrity and demands linguistic ability of a high order. "Black" English is not easier or less capable of encoding complex ideas--it is just different.

The issues raised by controversies over teaching in dialect, or taking account of dialect, are not simple. They involve all the important social and political problems of our time. Overemphasis on dialect should not seduce reading specialists into thinking that a modern sociolinguistic approach offers an ultimate key to reading problems, however. Venezky (1970) puts it well:

> Why so many middle-class standard speakers do not become adequate readers is still a mystery; hence, it should not be surprising that when non-standard speech and poverty are added, even the problem itself becomes obscured.

Experiments in other countries, to be reviewed later, suggest that the social components of linguistic-training programs probably overshadow language components.

SOCIOLINGUISTICALLY BASED SUGGESTIONS FOR TRAINING

Later in this section I will discuss some specific training programs that have grown out of current sociolinguistic research. I will now comment upon a few recommendations for improving reading that have been made on the basis of more general experience and research. These comments will emphasize sociological implications.

Home Activities

Certain activities of parents may aid reading achievement. A number of studies suggest that parental reading behavior and parental encouragement of the child's reading are associated with children's reading achievement (Gallup International, 1969a, 1969b; Rankin, 1967). Apart from specific tutelage in reading, one would expect children to adopt values similar to their parents and to imitate directly some parent behaviors; in other words, children expect to model the behavior of their parents. Some of the rewards and sanctions parents apply may have profound influence on attitudes and actions of children even when incentives are never made verbally explicit. How else can one explain the actions of a middle-class first-grader who cannot yet read but who insists on carrying a book bag loaded with heavy books back and forth to school?

Middle-class mothers are more likely than working-class mothers to read to their children (Milner, 1951; Robinson, 1968). This behavior, which could help mediate social-class differences in reading, in itself could increase vocabulary, train the child to listen, stimulate substantive interests that lead to further reading, and establish motivations and values that foster reading. Even before the age when reading aloud to children is begun, maternal activities may shape children's interests. Bing (1963), in a study of high-verbal and low-verbal children matched on IQ, finds that, compared with lower-class mothers, middle-class mothers give children more verbal stimulation during infancy and early childhood and let their children participate more in conversations. Hess and Shipman (1965) find school achievement related to black mothers' verbal production. Although actions of mothers are more often studied, fathers' actions in respect to reading may also be important (Bing, 1963). One wonders how much of boys' retardation in reading compared to girls' could be owing to the lesser availability of male-role models

for reading and for other verbal behaviors in the preschool years.

I must point out that other social-class-related characteristics besides verbal behavior or reading behavior could account for reading-achievement differences in the studies just cited since the data are entirely correlational. But some indication that linguistic or reading behaviors per se rather than other attributes of social class are causally related to reading can be drawn from a study by Irwin, cited by McCandless (1961). Children whose working-class mothers spend about 10 minutes per day reading to the child from 12 months to about 20 months of age achieved improvement in "all phases of speech." A similar result for two-year-olds of low-income families is reported by Fodor (1967) and by Jensen (1968, p. 120). Reading to a child between the ages of one and two has been shown to have very specific effects lasting for a long time. Burtt (1941) showed with his own child that Greek poetry read aloud to a child from the age of 15 months to 3 years produced savings in relearning at ages 8 and 14. The potential significance of this finding is hard to overestimate.

Other characteristics of these mothers which made them willing to read to their children on a schedule are confounded with the outcome, however. The mothers may have, in fact, tended to provide more of all kinds of verbal stimulation. To demonstrate convincingly effects of reading only would require that a group of children read to by adults, unbeknownst to mothers, show improvement. An early study along these lines with positive findings by Dawe (1942) reports IQ gains of 15 points that were significant beyond the .01 level, and gains in sentence complexity following about 50 hours of verbal interaction over a period of months between interested adults and five-year-old children living in an orphanage.

Sadly, no studies of parents' reading or verbal activities seem to take notice of parents' IQ. Thus, parents of high achievers in Rankin's (1967) study (found to exceed significantly parents of low achievers in having their children read aloud to them and in the quantity of their own reading) may merely be the highest-IQ parents among those sampled by Rankin. Intelligence differences among parents could by themselves account for the children's superior reading achievement in terms of genetic influences, environmental influences, or both.

School Activities Not Directly Related to Reading

The life styles or value systems of some social groups are organized around modes of social interaction that one

would judge to be ineffective, or even maladaptive, for reading instruction. A poignant example is the tendency of Warm Springs Indian children (Philips, 1970) to make bids for the attention of fellow students and to attend to what other students say rather than to what the teacher says. Social-interaction patterns in their homes and communities do not include a pattern where a single adult (teacher) is in a position of social control over younger persons. Both the social-control and language-interchange patterns of a typical classroom seem strange to these children and contradict their social and conversational customs. Unfortunately, when primary-school teachers adapt to the verbal interaction patterns of these Indian students, the benefits may vanish in the long run because at the next level of schooling teachers will not adapt and students are still not "socialized" to school. Exactly what would be an optimum course of action is not clear.

Labov (1970) similarly sees strong social pressures militating against reading achievement for some ghetto children. He finds that New York gang boys who are outstanding in their ability to handle language in story telling, explanation and argument, ritual insults, and other verbal forms of peer group culture asymptote at the fifth-grade level in reading skill. By contrast, boys who live close by, but who are not affiliated with gangs, continue to display upward progress in reading through the tenth grade. The socializing norms which govern school learning activities are congruent for one group of boys, and alienating for the other group.

Some efforts, discussed below, have been made to provide specific kinds of training for children whose backgrounds may not mirror those of middle-class white children. These efforts can supplement, emphasize, or counteract general training the children have received before they enter school.

An imaginative effort to improve reading readiness by Blank and Solomon (1968) involved training children in specific cognitive tasks such as learning to exclude one item from a list and in developing imagery for future events. These workers feel that "lubrication of the language system" by learning vocabulary is pointless, that what children need is to use language to structure and guide their thinking. This view holds much in common with one expressed in several places in this paper--that language and reading skill will be acquired mainly in contexts that are meaningful for the child in terms of his own motives and goals.

Other cognitive skills may be trainable and contribute to reading progress indirectly, although efforts have so far not been tied in directly to reading programs. The report by Lambert (1970) on trainable strategies of learning paired associates is an exception. For example, fifth-graders who tend not to identify problematic situations or to indicate

uncertainty about such situations can be trained to express uncertainty and to discriminate problematic statements (Sieber, Epstein, & Petty, 1970). Perhaps first-graders reared in subcultures where uncertainty is glossed over would be helped by specific training in recognizing and labeling problematic situations. The Gahagans' language program, to be discussed below, probably trains this cognitive skill.

I now turn to school programs growing directly out of research in sociolinguistics where reading is a major concern. Some foreign programs are particularly instructive because the social parameters of the school context are different from those inside the United States. This allows some guesses to be made about the relative importance of linguistic factors compared to social factors.

The Language Programme

A very extensive effort in England--"The Language Programme"--involving daily training of children from working-class families, was invented and is supervised by Bernstein's group. Several reports are now available on different aspects of the programs. For example, Coulthard and Robinson (1968) report that spending 20 minutes a day for 4-1/2 terms "doing a variety of tasks . . . to move the children towards the comprehension and use of an 'elaborated' code" caused low-IQ children (average IQ = 89) to perform better in language skills involving modification than high-IQ children (average IQ = 118) who did not receive the special training.

The reader should consult Gahagan and Gahagan (1970) for a comprehensive report on the overall program after three years' experience. Nine schools in a working-class section of London provided an experimental group (three schools) and two control groups (three schools each). One control group permits assessment of possible Hawthorne effects. The description of the program (Gahagan & Gahagan, 1970, pp. 33-60) suggests that perhaps more emphasis is placed on social restructuring and on cognitive style and less emphasis is placed on direct language training than the program has been given credit for. Many of the activities require that children work in groups or pairs (the telephones, drama, "I-am-the-teacher" activities). A preliminary analysis of children's control styles (Gahagan & Gahagan, 1970, Appendix B) shows that working-class children enrolled in the program have begun to use social-control techniques more like those of middle-class persons and less like those of lower-class persons, even though social-control techniques are not a topic of direct training in the program.

Many program activities point toward acquisition of cognitive skills; acquiring the language needed to express

logical relations, training in listening, sharpening ability to discriminate qualitative and quantitative differences, remembering and interpreting instructions, and encouraging recognition of the range of available alternatives. Some subtle aspects of the program, perhaps more important than any yet mentioned, involve the setting up of tasks where a restricted code would not be adequate, or of using unplanned or "natural" events as opportunities to elicit elaborated code. Osser (in press) calls these "low-context" situations, where the speaker has little or no shared background with his audience and where topics demand extensive preplanning and exposition.

If there is one generalization that can be made from research on developmental psycholinguistics to date, it is that young human beings will have little trouble learning and producing language that is instrumental for goals that they see as important. Any strategies that embody situations relevant in this sense, like those just mentioned where restricted code will not do the communication job, seem to succeed.

Unfortunately, there is little evidence so far of the impact of the Gahagans' language program on reading. A future study will incorporate reading-ability scores. The proportion of low-EPT scores (used in England to measure "educational attainment in general literacy") is reduced among children who have participated in the program.

Bilingual Experiments

Two well-controlled experiments in Montreal by Wallace Lambert and his associates (Lambert, 1970; Lambert & MacNamara, 1969; Lambert, Just, & Segalowitz, 1970) begin bilingual training in kindergarten and continue it during the early grades. Briefly, Canadian anglophone children are placed in kindergartens where French is spoken almost exclusively, and then throughout the first and second grades these children receive all their instruction in French. English continues as their "home" language.

In evaluations to date, the program has shown up astoundingly well. Children from two independent experiments show a high level of skill in receptive and productive aspects of French, a good command of English, and a high level of skill in nonlanguage subjects like mathematics taught through the foreign language only. Comparisons hold up against English control groups in the same school and in another school, and against a French control class in the same district.

A different kind of program, an alternate-day program in the Philippines where instruction in kindergarten and the

early grades is given one day in English and the next day in Tagalog, also leads to impressive performance in both languages. The Philippine program is not as elaborate as the Montreal experiments, but resembles them in that the teachers were handpicked for their competence and fluency, and were specially trained (Tucker, Otanes, & Sibayan, 1970).

These bilingual experiments would seem to parallel at least superficially the experiences of many children in the United States from homes where a dialect (Negro, Spanish, Indian, or Appalachian) is spoken and who enter schools where standard English is spoken. These children begin kindergarten where they hear "standard English," then start first grade, where they receive instruction in school subjects in "standard English." They thus continue in a dialect at home and hear standard English during school hours. Why is the outcome of this bi-dialectal experience, which so often leads to repeated failures and dropping out from school, so different from the outcome of the bilingual experiments with Montreal children? Offhand, it would seem to be much easier to learn a slightly modified version of a language one already speaks rather than a "foreign" language with a new lexicon, a different grammar, and a different phonology. Certain differences in the two situations should be noted, however.

1. In Montreal there is recognition by the students, by the teachers, by the parents, and by the community of the explicit task being undertaken. The task is clearly defined --to learn a second language--and is undertaken with great community enthusiasm and social support. In the United States, by contrast, until recently there has not been explicit recognition of the existence of minority dialects. There has rather been pressure against recognizing "Negro" speech. Schools have been slow to realize that a new dialect (standard English) may need to be acquired. The United States teacher has generally viewed the problem, if a problem were acknowledged to exist, as one of stamping out errors or of suppressing "vulgar" speech. In other words, the need for learning a new dialect was denied or twisted.

2. In Montreal, all the students in the bilingual program speak and hear nothing in school but French from the inception of the program. They are not competing with other children more fluent in the dialect than they. In the United States, students who speak a dialect will hear more than one dialect during school. The teacher may emphasize a standard dialect, but during school hours students may try to speak the standard dialect only when they address the teacher. They continue to speak the neighborhood dialect with their peers during school hours. Since a child who speaks a nonstandard dialect can be understood by a speaker of standard English, but the child who speaks English to a monolingual French Canadian cannot be understood, there is a great difference in the amount of pressure to use the new dialect.

3. In Montreal the social-reward system of the peer group and home setting is probably not changed by the speaking of French during school hours. In fact, learning and speaking French may lead to increases in the absolute amounts of social rewards available for distribution. On the other hand, in the United States black children often have white teachers, and in most places where social class differs between students and teachers, the students usually belong to the group of lower status. The absolute amounts of social rewards available for distribution are reduced. Even more important, speaking of standard English by members of lower SES groups in the United States may be severely punished by both the family and the peer group. Economic insecurity and life style produce great press toward group solidarity in the lower class. Its members look to neighbors and friends in time of need, spend proportionately much more leisure time with them than with others, and generally interact little outside of working hours with other groups (Cohen & Hodges, 1963). A threat exists, therefore, for the person who symbolically relinquishes membership in his group by taking up the speech style of another group. The deviant speaker has much to lose, for he cannot easily replace various social and financial supports the group extends if the group decides to "punish" his deviant speech behavior.

4. A point made earlier is especially relevant here. English and French are discriminably different and there is little confusion between the two when one is speaking or learning them. There is potentially great confusion between two highly similar dialects, however, and American linguists, such as Baratz and Labov, have pointed out the differential incidence of homologs to illustrate the difficulties in moving across dialects.

Psychological experiments on interference in learning suggest that, potentially, the greatest interference occurs when learning materials are highly similar (Entwisle & Huggins, 1963, 1964). The difficulty is undoubtedly worsened when the nature of the task is obscure. It is often not made clear that the task is to learn a new dialect and that there are specific points of contrast between dialects.

5. What is implied specifically for reading when the text and the teacher present one dialect and the student "reads" and speaks his own? Presumably, the child must decode standard English to nonstandard English in order to extract the meaning, and then attempt to render the passage aloud in standard English. The English-speaking Montreal child takes a page written in French and is asked to "read" it by rendering French graphemes into French phonemes. He will not be asked to decode it from printed French to spoken English. He is learning spoken French and there is no confusion in his mind about the correspondences between the written French

symbols and his knowledge of spoken French. The American child is required to combine the decoding and translating tasks and may start out by identifying graphemes of standard English with phonemes of another dialect.

This brief consideration of the Montreal experiments in light of the experience of children in the United States who speak nonstandard dialects suggests that parallels between the two sets of experiences may be more apparent than real.

So far, I have discussed the hypothetical course of events when children enter schools in the United States with no special program or facilities for dealing with dialect differences. What about schools where programs do exist? As mentioned earlier, there are no rigorous evaluations yet reported. Some work, recently undertaken, however, can be discussed even though it is far from complete.

In the United States there are now 58 Spanish-English programs for Mexican-Americans, 10 other Spanish programs, and 8 programs for Indians, Orientals, French, and Portuguese. These are funded by the Office of Education at an average first-year cost of $100,000. According to Gaarder (1970), the Office of Education has interpreted bilingual education officially to mean

> the use of two languages, one of which is English, as mediums of instruction . . . for the same student populations in a well-organized program that encompasses part or all the curriculum, plus study of the history and culture associated with a student's mother tongue [p. 164].

Gaarder, who himself is on the staff of the Office of Education, sees evidence that most of the "other-medium" teachers in these programs are not adequately prepared to conduct bilingual schooling. To a large extent the projects depend on the teaching services of aides, bilingual individuals usually drawn from the community, rarely required to be literate in the non-English tongue, and paid disproportionately low wages. Teachers are expected to teach mathematics, science, social studies, and language arts in the other medium; in other words, to invent instructional materials in substantive fields when they have very limited facility in the second language, perhaps enough only for small talk in the second language. Many of the programs do not have clear objectives. Some schedule only a few minutes daily for using the mother tongue as a medium. Aside from language competence, there are also issues concerning whether a single individual can fairly present two cultures.

Two strengths of the Montreal program seem missing in these American programs. The first is the caliber of the Montreal instruction. The kindergarten program "was conducted

almost exclusively in French by two very skilled and experienced teachers from Europe" and French was the only language used by the first-graders from the first day on. The curriculum was worked out carefully, using materials from both French-Canadian and European-French first grades. Second, the program was developed to satisfy a community-wide desire to promote effective bilingualism. The results are being watched with great interest by all concerned (parents, teachers, and administrators) and are not regarded as a remedial type of operation directed at children who are expected to be poor scholastic performers.

The contrast between the two efforts could be pursued further, but the point has been made. One cannot be very optimistic about bilingual programs in the United States. Fully bilingual programs (Ervin-Tripp, 1970) where speakers of standard English learn a nonstandard dialect while nonstandard speakers simultaneously learn standard English may go far toward mobilizing social forces that will aid dialect instruction. Minority-group children would then see others struggling to learn a new dialect and also see their dialect respected by having instruction delivered in it. There is no evidence yet available on fully bilingual programs.

The success of the Montreal experiments is hard to overlook. Short of actual parallel efforts in the United States, which seem unlikely on a number of grounds, perhaps the lessons to draw are that (a) there should be explicit recognition of the dialect learning problem, (b) decoding should be limited to a single dialect, and (c) strong efforts should be directed at improving social climates surrounding the learning task.

Demographic Incidence of Reading Failures

The topic of code and dialect switching and its relation to reading would not be complete without mention of transnational differences in reading disability. Some countries like Japan apparently experience negligible amounts of reading failure (Makita, 1968). For European countries, incidence of reading failure seems to decrease as one moves from English-speaking, to German, and then to Italian- and Spanish-speaking countries. Levin (1966) reports that in Italy he queried first-grade teachers and found that after three months all children could read anything presented to them. The relevance of such transnational comparisons is pointed up by a recent experimental demonstration that American children with reading problems can easily learn to read English represented by Chinese characters (Rozin, Poritsky, & Sotsky, 1971). These same children with simultaneous tutoring in English orthography did not improve.

The difficulties in making transnational comparisons are severe. What does "failure" mean in each place? How accurate are the figures? In what ways do the countries differ with respect to school starting age? These are only a few of the questions that come to mind. It is tempting to fasten on the phonemic regularity of Japanese and Italian in contrast with English as an explanation for the decreased number of reading failures in Japan and Italy. This is the explanation that Rozin and others seem to favor. Yet social and cultural differences among these countries are as great as any linguistic differences, so the social context of instruction and language-socialization practices could equally well account for the outcome. More data are needed on these provocative differences to pinpoint causal relationships.

Sex differences in reading failure are equally perplexing. Over 90 percent of referrals to reading clinics in the United States are males. This sex difference is apparently minimal in European countries, and in some places (Germany) there seems to be a higher incidence of reading disability in girls (Preston, 1962). It is surprising that so little attention has been paid both to sex differences and to national differences.

An Overview of Research Needs

Having discussed some of the specific socialization practices that are associated with reading achievement and some of the experiments and remedial programs now in progress, I turn in conclusion to a reconsideration of the theoretical background from which much of this work springs.

A summary of Bernstein's theory of linguistic codes (Gahagan & Gahagan, 1970) will aid the reader:

> Within a common language two distinct modes of speech can be isolated and different types of social relations and their accompanying modes of speech can be distinguished and formally described. Members of certain social classes will tend to be restricted to a particular type of social relation and therefore to a particular form of speech; and finally this restriction in terms of the current educational demands has negative consequences for them.

Bear in mind that Bernstein himself says (Gahagan & Gahagan, 1970):

> The concept "code" has nothing to do with such curious terms as standard and substandard English. It is not concerned with the availability to a child of syntax or even lexes . . . if there is a discrepancy and the meanings and their linguistic realization change . . . between

the home and the school, then for such children there will be initial difficulties [pp. 115-117].

As we have seen, some of the ongoing research in the United States related to Bernstein's theorizing aims not so much at documenting the existence of codes, the aim of many English studies, as at searching for socialization practices that lead to differences in language behavior or language use. Other American researchers, mainly those classed as sociolinguists, have been interested in describing dialects but not because, like Bernstein, they are interested in linking dialect differences to fundamental differences in social structure and role structure. Their interests are only incidentally sociological. They note that dialect distributions correlate with social stratification measures and that speech differences covary with the allocation of social and material resources, but they do not ask how dialect develops. They ask rather how forms of social interaction influence the quality of language. They vigorously dispute the idea that possessing language in one code or dialect rather than another leads to educational deficits for any reason except that the teacher, school, and community devalue the code together with the speakers of the code. They are attuned to the social-psychological aspects of interaction via language rather than to basic attributes of social structure that shape language.

The British and American points of view are not so different as they may at first appear, however, and their significance for reading derives from their view of communicative competence and how competence is acquired. Some points concerning code or dialect differences, or both, and educability need to be kept in mind in trying to see implications for practice.

1. The degree of code difference, presuming codes do exist, is hard to estimate now. Other variables are often confounded with class or race differences in studies of code differences. IQ is one. When Lawton, and others following Bernstein, match working-class and middle-class boys on IQ by selecting boys with IQ's of 100 from both groups, they are probably selecting boys who are somewhat atypical. Middle-class boys, on the average, obtain a higher IQ than working-class boys, so boys matched for IQ selected from each class are probably not representative of either. Neither are they likely to have mean IQ's of 100 on retest. If socialization practices and language use are being related, working-class boys with IQ's of 100 will tend to have parents whose IQ's are lower than theirs. Middle-class boys with IQ's of 100 will tend to have parents whose IQ's are higher than theirs. Consequently, regression to the means of the populations from which they were drawn will occur. Estimates of social-class effects may be biased when effects are judged on the basis of experiments carried out in samples selected in this way. If

true code differences are associated with social-class membership, we may not yet have very good ideas of the magnitude of these differences.

2. Specific results on linguistic development are hard to transfer from one area of the world to another. To repeat a point made earlier: the class structure of English society and the dialects associated with that class structure differ in many ways from American class structure and dialects. It is a large, perhaps insurmountable jump, from working-class English speakers to black American ghetto speakers, except in suggesting questions or methods of study. "Diminution of educability" in a British educational setting may have no clear parallel in the United States.

3. Code differences so far documented could be largely "situation" differences, a fact also noted earlier. When lower-class children speak to middle-class interviewers (or teachers) about topics unconnected with their own daily experiences, or with which they are not ego-involved, they may speak little and in ways that do not reflect their usual speech. Code "differences" could thus disappear or change when more appropriate situations for sampling language are arranged. This suggests that the problem of elicitation is the major educational one and that language competence already potentially available needs to be encouraged. Manipulation of social structure in the classroom may offer a potent means for elicitation.

4. Evidence from bilingual experiments suggests that social factors may dwarf linguistic factors in second-language learning. Reasoning by analogy, one might hypothesize that code differences may lead to different degrees of educability *mostly* because of social factors confounded with code differences, rather than because of linguistic or cognitive components of code *qua* code. Bernstein has repeatedly called attention to this, although his caveat sometimes goes unnoticed. The American sociolinguists who make the social-stigma argument so vehemently nevertheless work mostly on contrastive analyses to aid direct teaching of new codes--purely linguistic matters--rather than on educational studies evaluating the impact of social settings on language learning. Likewise the "programme" developed by Bernstein's group manipulates social-structure variables only incidentally. Paradoxically, the remedial efforts in both the United States and Great Britain manipulate variables that both the American sociolinguists and Bernstein say are secondary.

No research here or abroad directly challenges or tests Bernstein's basic social assumptions relating social contexts of language use and educability. No programs, so far as I know, even those designed under his eye, try to manipulate role relationships and *social* variables directly.

One might think, because Bernstein's theory stresses the contextual influences on speech, primary emphasis in remedial programs should be placed on the context for social and verbal interaction in schools or on changes in role relationships and techniques for social control. One looks for some revision or revamping of social roles in the school rather than for a 20-minutes-a-day dose of elaborated speech to be at the heart of English programs to improve educability. Cazden (1968) also observes this. Such is not the case, although as pointed out earlier, the description of the actual activities carried out in the classroom suggests that there are many indirect alterations of the role structure.

Many infant schools in Great Britain have reorganized classrooms to modify roles of teachers and students to a modest extent. Testimony to the general effectiveness of role alteration is the fact that students in these schools are apparently slightly ahead of students in traditional schools in reading achievement. According to the Plowden Report (1967), there seem to be few reading problems.

A task barely begun is that of analyzing correlations between social class and language development in terms of mediating variables (Cazden, 1966). What features of context are important? Affective quality? Whether the child talks with adults or other children? How varied contexts are? Relative exposure to conversation and TV? We know ghetto children watch TV a great deal, but what do they watch and how attentive are they? What features of linguistic models are important? Conformity to standard English? Linguistic variety? Sequencing of speech? Quality of speech? Which concept of dialect is important socially? The structuralist concept which focuses on grammar? Or the social concept which focuses on rhythm, intonation, and pronunciation? Many prominent blacks speak so that their messages contain enough standard English so whites can understand but at the same time signal to blacks their credibility (Cazden, Bryant, & Tillman, 1970). How does the quality and quantity of language in the classroom influence the child's general language development? As Osser (in press) says, we need to know how language functions for children of different ages and from different backgrounds in various educational contexts.

Reading cannot be viewed apart from total language development. What is germane for overall language development has to be germane for reading. It is easy to underrate the most obvious fact of all: children readily learn language when they interact with other people where meaning is important, where the functions of language in the life of the speaker are significant. Meaningless language drill can even have deleterious effects (Ervin-Tripp, 1970). This may explain why the massive exposure of ghetto children to language via TV has apparently had such small effects (Entwisle, 1966, 1968).

Just as learning theorists have generally ignored group differences, they have also ignored the social context within which learning takes place, whether this context accompanies group differences or is a factor operating alone. While this may be a minor omission for learning in T-mazes or Skinner boxes, it may be an overriding consideration in school learning. In schools, as Coleman (1961) points out, the fundamental competition is for peer-group status. Often, educational achievements lower rather than enhance such status. The social context, in other words, defines the rewards in the learning situation. While certain plausible statements can be made about how group differences may affect reading achievement, there is little that can be said specifically about the social context of reading instruction.

We see proficient readers in those groups for whom reading has importance--middle-class and upper-class groups. Those children who learn to read best are those who need to in order to make sense of their lives. Bernstein himself points out that there is nothing in a dialect (code) to prevent the child from learning universalistic meanings. If reading, however, is not carried on in a context to trigger the child's imagination or his curiosity, the child will not be engaged with the task. These motivations run deep; they are not aroused by surface features like pictures in texts or themes about minority-group characters. If schools draw from the symbolic world of the middle class, the non-middle-class child gropes around in a symbolic system which does not link him to the outside world. The basic requirement for language learning, relevance, is violated.

To sum up, group differences so far ignored by reading models include dialect differences, possible ethnic differences in information-processing skills, cognitive-style differences, and affective factors. Whether social-class differences are due mostly to genetic influences or to environmental influences, a controversial topic at the moment, is somewhat irrelevant here because the fact of group differences is not disputed. I suspect, however, that it is the social context surrounding group differences that may explain most of the variance. If this is true, then preparing primers in dialect or sequencing readers in terms of morphology may have small impact compared to the impact of changes in social variables. We badly need some educational programs where social structures are altered. We also need generally more rigorous and rich evaluation of programs already underway. Most of all, perhaps, we need development of sociolinguistic theory.

REFERENCES

Aarons, A. C., Gordon, B. Y., & Stewart, W. A. (Eds.) Linguistic-cultural differences and American education. The Florida FL Reporter, 1969, 7.

Anonymous. Social Science Research Council Items, 1969, 23, 17-26.

Baldwin, T., & Garvey, C. Studies in convergent communication: I. A measure of communication accuracy. Center for the Social Organization of Schools, The Johns Hopkins University, Baltimore, Maryland, 1970.

Baratz, J. C. A bi-dialectal task for determining language proficiency in economically disadvantaged Negro children. Child Development, 1969, 40, 889-902.

Baratz, J. C. Educational considerations for teaching standard English to Negro children. In R. W. Fasold & R. W. Shuy (Eds.), Teaching standard English in the inner city. Washington, D.C.: Center for Applied Linguistics, 1970. Pp. 20-40. (a)

Baratz, J. C. Teaching reading in an urban Negro school system. In F. Williams (Ed.), Language and poverty. Chicago: Markham, 1970. Pp. 11-25. (b)

Baratz, J. C., & Shuy, R. W. (Eds.) Teaching black children to read. Washington, D.C.: Center for Applied Linguistics, 1969.

Barritt, L. S., Semmel, M. I., & Weener, P. D. A comparison of the psycholinguistic functioning of "educationally-advantaged" and "educationally-deprived" children. Unpublished report, Center for Research on Language and Language Behavior, University of Michigan, 1968.

Battle, E. S., & Rotter, J. B. Children's feelings of personal control as related to social class and ethnic group. Journal of Personality, 1963, 31, 482-490.

Beasley, D. S., & Dickie, D. C. Auditory reassembly abilities of black and white first- and third-grade children. Department of Audiology and Speech Sciences, Michigan State University, 1971. (Mimeographed)

Bee, H. L., VanEgeren, L. F., Streissguth, A. P., Nyman, B. A., & Leckie, M. S. Social class differences in maternal teaching strategies and speech patterns. Developmental Psychology, 1969, 1, 726-734.

Bee, H. L., Nyman, B. A., Pytkowicz, A. R., Sarason, I. G., & VanEgeren, L. A study of cognitive and motivational

variables in lower and middle class preschool children: An approach to the evaluation of the impact of Head Start. Research Report No. 8, Contract OEO 1375, University of Washington, 1970.

Bernstein, B. Language and social class. British Journal of Sociology, 1960, 11, 271-276.

Bernstein, B. Linguistic codes, hesitation phenomena, and intelligence. Language and Speech, 1962, 5, 31-46.

Bernstein, B. Elaborated and restricted codes: An outline. International Journal of Applied Linguistics, 1967, 33, 126-133.

Bernstein, B. Social class, language, and socialization. Unpublished manuscript, Institute of Education, London University, 1970. (a)

Bernstein, B. A sociolinguistic approach to socialization: II. Family role systems, social control, and communication. The Human Context, 1970, 2, 233-247. (b)

Bernstein, B. A sociolinguistic approach to socialization: With some reference to educability. In J. J. Gumperz & D. Hymes (Eds.), Directions in sociolinguistics. New York: Holt, Rinehart, & Winston, 1971, in press.

Bernstein, B., & Henderson, D. Social class differences in the relevance of language to socialization. Sociology, 1969, 3, 1-20.

Bing, E. Effect of child-rearing practices on development of differential cognitive abilities. Child Development, 1963, 34, 631-648.

Blank, M. Cognitive processes in auditory discrimination in normal and retarded readers. Child Development, 1968, 39, 1091-1011.

Blank, M., & Solomon, F. A tutorial language program to develop abstract thinking in socially disadvantaged preschool children. Child Development, 1968, 39, 379-390.

Bond, G. L. The auditory and speech characteristics of poor readers. Teachers College Contributions to Education, 1935, No. 657.

Brent, S. B., & Katz, E. W. A study of language deviations and cognitive process. Progress Report No. 3, 1967, Research Contract 1209, Office of Economic Opportunity Job Corps.

Bruner, J. S. Child care and social class. Unpublished manuscript, March, 1970, cited by J. S. Bruner, Poverty and childhood. Paper presented at the Annual Citation Awards, Merrill-Palmer Institute, Detroit, June 9, 1970.

Bruner, J. S., & Goodman, C. C. Value and need as organizing factors in perception. Journal of Abnormal and Social Psychology, 1947, 42, 33-44.

Burtt, H. E. An experimental study of early childhood memory: Final report. Journal of Genetic Psychology, 1941, 58, 435-439.

Carroll, J. B. The nature of the reading process. In Language and reading. Washington, D.C.: Center for Applied Linguistics, 1970. Pp. 26-37.

Cazden, C. B. Environmental assistance to the child's acquisition of grammar. Unpublished doctoral dissertation, Harvard University, 1965.

Cazden, C. B. Subcultural differences in child language: An interdisciplinary review. Merrill-Palmer Quarterly, 1966, 12, 185-219.

Cazden, C. B. Three sociolinguistic views of the language and speech of lower-class children: With special attention to the work of Basil Bernstein. Developmental Medicine and Child Neurology, 1968, 10, 600-612.

Cazden, C. B. Suggestions from studies of early language acquisition. Childhood Education, 1969, 1, 127-131.

Cazden, C. B. Language in early childhood and reading: A review for 1969. ERIC Clearinghouse in Linguistics, Washington, D.C., 1970.

Cazden, C. B., Bryant, B. H., & Tillman, M. A. Making it and going home: The attitudes of black people toward language education. Third Lincolnland conference on dialectology. Tuscaloosa: University of Alabama Press, 1970, in press.

Clark, A. S., & Richards, C. J. Auditory discrimination among economically disadvantaged and nondisadvantaged pre-school children. Exceptional Children, 1966, 33, 259-262.

Cohen, A. K., & Hodges, H. M. Characteristics of the lower-blue-collar class. Social Problems, 1963, 10, 303-334.

Cohen, P. S. Outline of research on the English of Negro and Puerto Rican speakers in New York City. Project Literacy Report, No. 7. Ithaca: Cornell University, September, 1966.

Coleman, J. S. The adolescent society. New York: Free Press, 1961.

Coleman, J. S. Equality of educational opportunity. Washington, D.C.: U.S. Office of Education, 1966.

Cook, J. Familial processes of communication and control. In W. Brandis & D. Henderson (Eds.), Primary socialization, language, and education, Vol. I: Social class, language, and communication. London: Routledge & Kegan Paul, 1970.

Coulthard, R. M., & Robinson, W. P. The structure of the nominal group and elaboratedness of code. Language and Speech, 1968, 11, 234-250.

Covington, M. V. Some effects of stimulus familiarization on discrimination. Unpublished doctoral dissertation, University of California, 1962. Cited by A. R. Jensen, Social class and perceptual learning. Mental Hygiene, 1966, 50, 226-239.

Davis, A. Social class influences upon learning. Cambridge: Harvard University, 1948.

Dawe, H. C. A study of the effect of an educational program upon language development and related mental functions in young children. Journal of Experimental Education, 1942, 11, 200-209.

Deutsch, C. P. Auditory discrimination and learning: Social factors. Merrill-Palmer Quarterly, 1964, 10, 267-296.

Deutsch, M. The role of social class in language development. American Journal of Orthopsychiatry, 1965, 35, 24-35.

Eisenberg, L. Reading retardation: I. Psychiatric and sociological aspects. In Language and reading. Washington, D.C.: Center for Applied Linguistics, 1970. Pp. 186-208.

Entwisle, D. R. Word associations of young children. Baltimore: The Johns Hopkins Press, 1966.

Entwisle, D. R. Developmental sociolinguistics: Inner-city children. American Journal of Sociology, 1968, 74, 37-49.

Entwisle, D. R. Semantic systems of children: Some assessments of social class and ethnic differences. In F. Williams (Ed.), Language and poverty. Chicago: Markham Publishing, 1970. Pp. 123-140.

Entwisle, D. R., & Huggins, W. H. Interference in the learning of circuit theory. Proceedings of Institute of Electronic and Electrical Engineers, 1963, 51, 986-990.

Entwisle, D. R., & Huggins, W. H. Interference in meaningful learning. Journal of Educational Psychology, 1964, 55, 75-78.

Entwisle, D. R., Grafstein, D., Kervin, J., & Rivkin, M. Giant steps: A game to enhance semantic development of verbs. Report No. 81, 1970, Center for the Social Organization of Schools, The Johns Hopkins University, Baltimore, Maryland.

Entwisle, D. R., & Webster, M. A. Raising children's expectations for their own performance: A classroom application. Unpublished manuscript, Department of Social Relations, The Johns Hopkins University, March, 1971.

Ervin, S. M. Imitation and structural change in children's language. In E. Lenneberg (Ed.), New directions in the study of language. Cambridge, Mass.: M.I.T. Press, 1964. Pp. 163-189.

Ervin-Tripp, S. M. Language development. In M. Hoffman & L. Hoffman (Eds.), Review of child development. Vol. II. New York: Russell Sage, 1966. Pp. 55-106.

Ervin-Tripp, S. M. Sociolinguistics. Working Paper No. 3, November, 1967, University of California, Berkeley, Language Behavior Research Laboratory.

Ervin-Tripp, S. M. Structure and process in language acquisition. In J. E. Alatis (Ed.), 21st annual roundtable. Washington, D.C.: Georgetown University Press, 1970. Pp. 313-354.

Estes, W. K. Learning theory and mental development. New York: Academic Press, 1970.

Fasold, R. W., & Shuy, R. W. (Eds.) Teaching standard English in the inner city. Washington, D.C.: Center for Applied Linguistics, 1970.

Fodor, E. M. The influence of a program of reading on children's language development. Journal of Communication Diseases, 1967, 1, 246-252.

Gaarder, A. R. The first 76 bilingual education projects. In J. E. Alatis (Ed.), 21st annual roundtable. Washington, D.C.: Georgetown University Press, 1970. Pp. 163-179.

Gahagan, D. M., & Gahagan, G. A. Talk reform. London: Routledge & Kegan Paul, 1970.

Gallup International. The influence of home environment on the success of first graders as viewed by the mothers of

first grade students. Institute for Development of Educational Activities, Inc., 1969. (a)

Gallup International. The influence of home environment on the success of first graders as viewed by teachers of the first grade. Institute for Development of Educational Activities, Inc., 1969. (b)

Garvey, C. Personal communication, 1971.

Geyer, J. J. Models of perceptual processes in reading. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 47-94.

Gibson, E. J. Principles of perceptual learning and development. New York: Appleton-Century-Crofts, 1969.

Gibson, E. J. Learning to read. In Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 315-334.

Gibson, J. J. The visual world. New York: Houghton Mifflin, 1950.

Goodman, K. S. Dialect barriers to reading comprehension. Elementary English, 1965, 42, 853-860.

Graves, N. B. Child-rearing patterns and maternal perceptions of locus of control. Paper presented at the meeting of the American Anthropological Association, San Diego, California, 1970.

Gumperz, J. J. Verbal strategies in multilingual communication. In J. E. Alatis (Ed.), 21st annual roundtable. Washington, D.C.: Georgetown University Press, 1970. Pp. 129-148.

Gunderson, D. (Ed.) Language and reading. Washington, D.C.: Center for Applied Linguistics, 1970.

Gussow, J. Language development in disadvantaged children. IRCD Bulletin, 1965, 1, 5.

Hawkins, P. R. Social class, the nominal group and reference. Language and Speech, 1969, 12, 125-135.

Heider, E. R., Cazden, C. B., & Brown, R. Social class differences in the effectiveness and style of children's coding ability. Project Literacy Reports, No. 9. Ithaca: Cornell University, 1968.

Henderson, D. Contextual specificity, discretion and cognitive socialization: With specific reference to language.

Sociological Research Unit of the Department of Sociology, Institute of Education, University of London, 1969. (Mimeographed)

Hess, R. D., & Shipman, V. C. Early experience and socialization of cognitive modes in children. Child Development, 1965, 36, 869-886.

Hess, R. D., Shipman, V. C., Brophy, J. E., & Bear, R. M. The cognitive environments of preschool children. Unpublished manuscript, Graduate School of Education, University of Chicago, 1968.

Hess, R. D., Shipman, V. C., Brophy, J. E., & Bear, R. M. The cognitive environments of preschool children: Follow-up phase. Unpublished manuscript, Graduate School of Education, University of Chicago, 1969.

Hildreth, G. Readiness for school beginners. Yonkers-on-Hudson: World Book Co., 1950.

Hochberg, I., & Geffner, D. S. Verbal interpretation of environmental sounds by disadvantaged and non-disadvantaged children. Unpublished manuscript, School of Education, New York University, 1969.

Horn, T. D. (Ed.) Reading for the disadvantaged: Problems of linguistically different learners. New York: Harcourt, Brace, & World, 1970.

Hymes, D. Bilingual education: Linguistic vs. sociolinguistic bases. In J. E. Alatis (Ed.), 21st annual roundtable. Washington, D.C.: Georgetown University, 1970. Pp. 69-76.

Irwin, O. C. Cited by B. McCandless, Children and adolescents: Behavior and development. New York: Holt, Rinehart, & Winston, 1961.

Jensen, A. Social class and verbal learning. In M. Deutsch, I. Katz, & A. R. Jensen (Eds.), Social class, race, and psychological development. New York: Holt, Rinehart, & Winston, 1968. Pp. 115-174.

Jones, J. Social class and under-fives. December, 1966. Cited by B. Bernstein & D. Henderson, Social class differences in the relevance of language to socialization. Sociology, 1969, 3, 1-20.

Karnes, M. B. Research and development programs on preschool disadvantaged children. Vols. I, II, III. Washington, D.C.: U.S. Department of Health, Education, and Welfare, 1969.

Kashinsky, M., & Wiener, M. Tone in communication and the performance of children from two socioeconomic groups. Child Development, 1969, 40, 1193-1202.

Katz, J. The philosophy of language. New York: Harper & Row, 1968.

Kessel, F. The role of syntax in children's comprehension from ages six to twelve. Monographs of the Society for Research in Child Development, 1970, 36, No. 6.

Klaus, R. A., & Gray, S. W. The early training project for disadvantaged children: A report after five years. Monographs of the Society for Research in Child Development, 1968, 33, No. 4.

Krauss, R. M., & Rotter, G. S. Communication abilities of children as a function of status and age. Merrill-Palmer Quarterly, 1968, 14, 161-173.

Labov, W. Some sources of reading problems for Negro speakers of non-standard English. In A. Frazier (Ed.), New directions of elementary English. Chicago: National Council of Teachers of English, 1967. Pp. 140-167.

Labov, W. The study of non-standard English. ERIC Clearinghouse for Linguistics, 1969.

Labov, W. Systematically misleading data from test questions. Colloquium, April, 1970, School of Social Work and Department of Linguistics, University of Michigan. (Mimeographed)

Labov, W., & Cohen, P. Systematic relations of standard and non-standard rules in the grammars of Negro speakers. Project Literacy Reports, No. 8. Ithaca: Cornell University, 1967.

Lambert, N. Paired associate learning, social status, and tests of logical concrete behavior as univariate and multivariate predictors of first-grade reading achievement. American Educational Research Journal, 1970, 7, 511-528.

Lambert, W. E., & MacNamara, J. Some cognitive consequences of following a first-grade curriculum in a second language. Journal of Educational Psychology, 1969, 60, 86-96.

Lambert, W. E., Just, M., & Segalowitz, N. Some cognitive consequences of following the curricula of the early school grades in a foreign language. In J. E. Alatis (Ed.), 21st annual roundtable. Washington, D.C.: Georgetown University Press, 1970. Pp. 229-279.

Lawton, D. Social class, language, and education. New York: Schocken Books, 1968.

Lesser, G. S., Fifer, G., & Clark, D. H. Mental abilities of children in different social and cultural groups. Monographs of the Societ for Research in Child Development, 1965, 30, No. 4.

Levin, H. Reading research: What, why, and for whom. Elementary English, 1966, 43, 138-147.

Loban, W. D. The language of elementary-school children. (Research Report No. 1) Champaign, Ill.: National Council of Teachers of English, 1963.

Lundsteen, S. W., & Fruchter, B. Final Report, December, 1969, University of Texas at Austin, Grant No. OEG-7-0-530077-011-(010).

McArdle, M. T. Auditory discrimination in preschool children. Unpublished master's thesis, University of Tennessee, 1965. Cited by C. P. Deutsch, Social class, race, and psychological development. New York: Holt, Rinehart, & Winston, 1968. Pp. 58-85.

McCarthy, D. A. Language development. In L. Carmichael (Ed.), A manual of child psychology. New York: Wiley, 1946. Pp. 492-630.

Makita, K. The rarity of reading disability in Japanese children. American Journal of Orthopsychiatry, 1968, 38, 599-614.

Miller, G. Language and communication. New York: McGraw-Hill, 1951.

Milner, E. A study of the relationship between reading readiness in grade-one school children and patterns of parent-child interaction. Child Development, 1951, 22, 95-112.

Mohan, B. A. Sociolinguistics and context-dependence. Unpublished manuscript, University of Calgary, 1970.

Osser, H. Developmental studies of communicative competence. Paper presented at the Conference on Approaches to Social Dialects, Center for Applied Linguistics, Washington, D.C., 1969.

Osser, H. Biological and social factors in language development. In F. Williams (Ed.), Language and poverty. Chicago: Markham Publishing, 1970. Pp. 248-265.

Osser, H. Language development. In G. S. Lesser (Ed.), Psychology and educational practices. Scott, Foresman, in press.

Osser, H., & Harvey, K. Organizational properties of children's speech. Cited by H. Osser, Developmental studies of communicative competence. Paper presented at the Conference on Approaches to Social Dialects, Center for Applied Linguistics, Washington, D.C., 1969.

Osser, H., Wang, M. D., & Zaid, F. The young child's ability to imitate and comprehend speech: A comparison of two subcultural groups. Child Development, 1969, 40, 1063-1075.

Packer, A. B. Sylvia Ashton-Warner's methods tried in four United States cities. University of Florida, 1969. (Mimeographed)

Peisach, E. C. Children's comprehension of teacher and peer speech. Child Development, 1965, 30, 467-480.

Philips, S. U. Acquisition of rules for appropriate speech usage. In J. E. Alatis (Ed.), 21st annual roundtable. Washington, D.C.: Georgetown University Press, 1970. Pp. 77-101.

Plowden, B., et al. Children and their primary schools. Vols. 1 and 2. London, England: Her Majesty's Stationery Office, 1967.

Preston, R. C. Reading achievement of German and American children. School and Society, 1962, 90, 350-354.

Rackstraw, S. J., & Robinson, W. P. Social and psychological factors related to variability of answering behavior in five-year-old children. Language and Speech, 1967, 10, 88-106.

Rankin, P. T. The relationship between parent behavior and achievement of inner-city elementary-school children. Paper presented at the Annual Meeting of the American Educational Research Association, New York, February, 1967.

Raph, J. Language characteristics of culturally disadvantaged children: Review and implications. Review of Educational Research, 1965, 35, 373-400.

Robertson, J. E. Reading comprehension: A linguistic point of view. Paper presented at the meeting of the American Educational Research Association, Minneapolis, 1970.

Robinson, W. P. Cloze procedures as a technique for the investigation of social class differences in language usage. Language and Speech, 1965, 8, 42-55. (a)

Robinson, W. P. The elaborated code in working-class language. Language and Speech, 1965, 8, 241-244. (b)

Robinson, W. P. Social factors and language development in primary-school children. Proceedings of European seminar in sociology of education. Noordwijk, The Hague: Mouton, 1968.

Rosen, C. L., & Ortego, P. D. Language and reading problems of Spanish speaking children in the Southwest. Journal of Reading Behavior, 1969, 1, 57-67.

Rozin, P., Poritsky, S., & Sotsky, R. American children with reading problems can easily learn to read English represented by Chinese characters. Science, 1971, 171, 1264-1267.

Ruddell, R. B. An investigation of the effect of the similarity of oral and written patterns of language structure on reading comprehension. Unpublished doctoral dissertation, School of Education, Indiana University, 1963.

Ruddell, R. B. The effect of oral and written patterns of language structure on reading comprehension. Reading Teacher, 1965, 18, 270-275.

Sampson, O. C. Reading skill at eight years in relation to speech and other factors. British Journal of Educational Psychology, 1962, 32, 12-17.

Schwartz, D., Sparkman, J. P., & Deese, J. The process of understanding and judgments of comprehensibility. Journal of Verbal Learning and Verbal Behavior, 1970, 1, 87-93.

Shire, M. The relation of certain linguistic factors to reading achievement of first-grade children. Unpublished doctoral dissertation, Fordham University, 1945.

Shriner, T. H. Sociolinguistics and language. In L. Travis (Ed.), Handbook of speech pathology. New York: Appleton-Century-Crofts, 1969.

Shuy, R. W. Some considerations for developing beginning reading materials for ghetto children. Journal of Reading Behavior, 1969, 1, 33-43.

Sieber, J. E., Epstein, M., & Petty, C. Teaching children to indicate uncertainty and to discriminate between

problematic and non-problematic statements. Research and Development Memorandum No. 64, Stanford Center for Research and Development in Teaching, School of Education, Stanford University, March, 1970.

Sigel, I., Herman, P., & Hanesia, H. Styles of categorization and their intellectual and personality correlates in young children. Human Development, 1967, 10, 1-17.

Singer, H. Theoretical models of reading: Implications for teaching and research. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 147-182.

Smith, M. E. A study of some factors influencing the development of the sentence in pre-school children. Journal of Genetic Psychology, 1935, 46, 182-212.

Stolz, W. S., & Legum, S. E. The role of dialect in the school socialization of lower class children. Final Report on Head Start Evaluation and Research, 1966-1967, University of Texas at Austin, Contract No. 66-1, Child Development Evaluation and Research Center, 1967.

Strandberg, T. E. A study of the effects of training in visual literacy on verbal language behavior. Journal of Communication Disorders, 1969, 2, 252-263.

Strickland, R. G. The language of elementary school children: Its relationship to the language of reading textbooks and the quality of reading of selected children. Bulletin of the School of Education, Indiana University, 1962, 38, 1-131.

Tucker, G. R., Otanes, F. T., & Sibayan, B. P. An alternate day's approach to bilingual education. In J. E. Alatis (Ed.), 21st annual roundtable. Washington, D.C.: Georgetown University Press, 1970. Pp. 281-300.

Turner, G. J., & Pickvance, R. E. Social class differences in the expression of uncertainty in five-year-old children. Unpublished manuscript, University of London, Institute of Education, 1970.

Venezky, R. L. Non-standard language and reading. Working Paper No. 43. Madison: Wisconsin Research and Development Center for Cognitive Learning, University of Wisconsin, 1970.

Venezky, R. L., Calfee, R. C., & Chapman, R. S. Skills required for learning to read: A preliminary anaylsis. Working Paper No. 10. Madison: Wisconsin Research and

Development Center for Cognitive Learning, University of Wisconsin, 1968.

Weener, P. D. Social dialect differences and the recall of verbal messages. Journal of Educational Psychology, 1969, 60, 194-199.

Wepman, J. M. Auditory discrimination, speech, and reading. Elementary School Journal, 1960, 60, 325-334.

Wheeler, L. R., & Wheeler, V. D. A study of the relationships of auditory discrimination to silent reading abilities. Journal of Educational Research, 1954, 48, 103-113.

Williams, F. Psychological correlates of speech characteristics: On sounding "disadvantaged." Journal of Speech and Hearing, 1970, in press.

Williams, F., & Naremore, R. C. Language and poverty: An annotated bibliography. Madison: University of Wisconsin, Institute for Research on Poverty, 1967.

Williams, F., & Naremore, R. C. On the functional analysis of social class differences in modes of speech. Speech Monographs, 1969, 36, 77-102.

THEORIES OF LANGUAGE ACQUISITION IN RELATION TO BEGINNING READING INSTRUCTION*

Ronald Wardhaugh

University of Michigan

INTRODUCTION

Numerous summaries of research in language acquisition exist: McCarthy (1954) summarizes work completed prior to 1950; Elkonin (1958), Brown and Berko (1960), Carroll (1960), Brown (1965), Ervin-Tripp (1966), Ervin-Tripp and Slobin (1966), McNeill (1966, 1970a, 1970b), and Slobin (1971) summarize parts, or the whole, of more recent work; and Kelley (1967) provides one of the most interesting discussions of many of the major issues. The purpose of this paper is to isolate and assess major theories of language acquisition and to relate these theories to beginning reading instruction. The particular focus is the acquisition of syntax. The theories are also reviewed from the perspective of the linguistic knowledge available today; consequently, certain cognitive and affective factors are minimized. These factors are not to be considered unimportant in beginning reading instruction; rather, they are to be considered beyond the scope of this paper.

LANGUAGE ACQUISITION

Atheoretical Studies

A reading of McCarthy's summary article (1954) induces mixed feelings in anyone trained in linguistics. She reports on a wide variety of descriptive and normative studies, but all seem unrevealing insofar as current interests in language acquisition are concerned. The studies reported appear atheoretical today because the investigators made little attempt to formulate and test fruitful hypotheses and to handle data other than quantitatively. Consequently, no coherent account

---

*The author is grateful to Patricia Dishuck and Mary Ann Gatten for their assistance.

of language acquisition emerges from the studies reviewed by McCarthy. Instead, child language appears to drift somehow from a prevocalic stage, through various stages replete with errors and deficiencies, toward the clearly articulated speech of an ideal speaker of Standard English. As a result, sounds "emerge" in ways that are never specified, "first words" are uttered at a characteristic time, grammatical distinctions are "acquired," often through the elimination of various "errors," and vocabularies "expand" as the child's dictionary gains more entries. Gradually, by some process of making successive approximations, the child's language becomes more and more like the language ascribed in traditional grammars to those who speak the language "properly."

Working in such a way, investigators may try to discover when the child learns to distinguish pin from pen and witch from which, all the while ignoring the fact that in certain dialects such distinctions are not made at all. Or they may try to count various sentence types using formulae for sentence description that derive from analyses of writing and studies of rhetorical devices rather than from any close observation of spoken language. Or they may calculate word frequencies and compute type-token ratios without defining the concept of "a word" or devising the most appropriate elicitation procedures. Such investigators often collect considerable quantities of data which can be neatly inventoried and displayed in tables and figures (for example, tables of errors in articulation which show a gradual reduction in frequency as age increases). However, the data are essentially unrevealing because the investigators do not ask why it is that one linguistic skill is acquired before another, or what is the nature of the linguistic ability of the child at various stages in his linguistic development.

Only in recent years have such questions been asked by psychologists and linguists engaged in the study of language acquisition. They have realized that inventories are unrevealing unless they show which items contrast with each other within the inventories. They no longer disregard regional and social variations in speech and developments in modern linguistics. They insist that it is impossible to describe language acquisition without first spelling out either a specific theory of language or a general theory of learning. Recent work on language acquisition, therefore, confronts these theoretical issues. It does so at the expense of large-scale data collection, investigators preferring to test out hypotheses on as few as two or three children, as Brown and Bellugi (1964) did with Adam and Eve, or on a single phonological, grammatical, or semantic distinction, as Klima and Bellugi (1966) did with negation.

One issue that has never been dealt with satisfactorily, even in recent work, is the specification of the ultimate

linguistic knowledge or ability that is being acquired. Obviously, more is involved than knowledge of a dictionary or of an inventory of sentence patterns, or the ability to combine words and patterns. N. Chomsky (1965) has proposed the term competence, as distinguished from performance, to describe this knowledge. However, this term has become more of a slogan than a well-defined concept in linguistics. Since research in language acquisition must focus on such issues as "increasing complexity" and "developing competence," a certain vagueness results when the end point toward which the child is assumed to be progressing still remains largely hidden from view. Menyuk (1969) discusses some of the problems that result in attempts to interpret data in such circumstances. Fortunately, many of the data are not in dispute among those who study language acquisition, for all agree that certain stages or trends can be observed: babbling ends around 18 months; holophrastic utterances precede two- and three-word utterances; early speech is "telegraphic"; control of word order antedates control of inflections; and comprehension outstrips production. The interpretation of the data is the crucial issue.

Behavioristic Theories

In his book Verbal Behavior, Skinner (1957) proposes a comprehensive theory of language acquisition and language behavior in which specific linguistic behaviors are acquired through operant conditioning and then extended through response generalization. The devastating review of the book by N. Chomsky (1959) demonstrates the inappropriateness of Skinner's proposal. His criticisms reiterate earlier arguments from Syntactic Structures (1957) that existing theories of language are inadequate for almost any purpose and that the kind of theory he himself proposes is needed. The review also attacks the adequacy of reinforcement theory and the notion of generalization, as formulated by Skinner, in explaining either language acquisition or language behavior. Chomsky claims that the theory is illusionary, that most of its concepts are irrelevant in explaining linguistic behavior, and that the real issues are never confronted. Chomsky (1959) is particularly critical of Skinner's failure to recognize the contribution that the child makes to language acquisition, declaring that:

> . . . a refusal to study the contribution of the child to language learning permits only a superficial account of language acquisition, with a vast and unanalyzed contribution attributed to a step called "generalization" which in fact includes just about everything of interest in this process. If the study of language is limited in these ways, it seems inevitable that major aspects of verbal behavior will remain a mystery [p. 58].

However, in spite of Chomsky's criticisms of the inadequacy of conditioning or reinforcement theories to explain language acquisition, such theories are still proposed. Staats and Staats (1962, 1963, 1968), for example, use such terms as operant learning, reinforcing stimuli, time and scheduling of reinforcement, successive approximation, chaining, extinction, and discrimination and generalization to explain how language is acquired. Such concepts can only weakly explain why all children exhibit much the same pattern of development, how they construct novel utterances even in the earliest days of language use, and in what ways they master the abstract relationships that are not readily apparent in the utterances they hear. This last point is extremely important because, as Garrett and Fodor (1968) argue, the facts of language are abstractions which children must acquire from masses of highly variable data. Language is a mentalistic phenomenon, and S-R theories are unable to account for either its acquisition or use. The theory proposed by Staats and Staats involves the learning of a finite set of responses according to certain probabilities of occurrence. On the other hand, the current view is that a language is an infinite set of responses that are available to a speaker, and that language use is essentially creative. Probability has little to do with language use, although, of course, certain linguistic usages can be conditioned to events in the world once such usages have been acquired.

Jenkins and Palermo (1964) proposed a theory of language acquisition that recognizes some recent linguistic advances. The basic problem they see in language acquisition is that of explaining how the child acquires the frames of a phrase-structure grammar and the ability to substitute items within these frames. They propose that the child learns the stimulus-and-response equivalences that can occur in the frames. They heavily emphasize imitation, either overt or covert, as a force in establishing bonds between stimuli and responses, and they claim that the child generalizes to form classes of responses. However, they do not explain how control of such classes allows the child to construct longer sentences. Their theory does not attempt to analyze complex issues; it merely hints at them. The linguistic theory that Jenkins and Palermo propose is one N. Chomsky (1957) criticizes for being inadequate in that it does not account for the abstract nature of linguistic knowledge. Weksel (1965) is also critical of their proposal, claiming that it is linguistically inadequate and nowhere comes to grips with its central concept of generalization.

Another theory of language acquisition cast in the behavioristic mold comes from Braine (1963a, 1963b, 1965). This theory involves the principle of "contextual generalization," according to which the child observes that certain sets

of items occur in certain positions. He makes generalizations about positions rather than about the sets of items that occupy them. The positions themselves are not simply linear, but may be hierarchical. Consequently, the theory attempts to explain how the child acquires the hierarchical grammatical structures of sentences. Braine claims that transformations can be learned through contextual generalization. If they cannot, he declares that the failure argues as much for a reshaping of linguistic theory as it does for a reshaping of the principle of contextual generalization:

> If there is a possibility that the simpler of two possible grammatical solutions might require the more complex acquisition theory, then the domain over which simplicity is taken cannot be restricted to grammar alone and must include acquisition theory--otherwise the grammarian merely purchases simplicity at the psychologist's expense [1965, p. 491].

Slobin (in press) objects to Braine's proposal, citing evidence from a variety of languages. Bever, Fodor, and Weksel (1965a, 1965b) argue that no dominant patterns of word order exist for the child to generalize from, even in a language such as English, and that word ordering also occurs during language acquisition when the language has free word order. They say that the child must learn abstract structures for which no word-order patterns exist in the data to which he is exposed. Answering this last criticism, Braine (1965) points out that data do exist and that closer attention must be paid to how the child uses these data in the process of acquiring language.

Nativist Theories

Lenneberg (1967) proposes a theory of language acquisition heavily buttressed by biological evidence from studies of normal language development in children and of abnormal language development brought about congenitally, as in nanocephalic dwarfism, or environmentally, as in brain damage or aphasia. He emphasizes the development of the organism's capacities and shows how these mature along a fairly fixed schedule. Language emerges during this maturational process when anatomical, physiological, motor, neural, and cognitive developments allow it to emerge. Every child must learn the specific details of the language of his community, but the ability to learn language is innate and part of the biological endowment of the organism. The learning mechanisms, such as certain modes of perception, abilities in categorization, and capacities for transformation, are biologically given. According to Lenneberg, the child "resonates" to the language of his environment during the acquisition process; however, he never clearly specifies exactly what resonance is. One of

Lenneberg's most interesting observations is that there is a critical, biologically determined period for language acquisition between the ages of two and twelve.

Since Lenneberg is interested in the biological bases of language acquisition, he has almost nothing to say about how particular linguistic items are learned, except to deny that statistical probability and imitation are important in the process. He claims that language acquisition is a natural activity, much as learning to walk is a natural activity. Both activities occur universally unless a pathological condition exists. Learning, as this term is traditionally defined, is not involved. Instead, Lenneberg carefully locks language acquisition into the general biological development of the organism.

McNeill (1966, 1968, 1970a, 1970b) takes a rather different nativist position toward language acquisition. He says that anyone who wishes to study the problem of language acquisition must begin with a knowledge of what it is that the child must acquire:

> A major requirement for any theory of language acquisition is that it explain a known phenomenon, which means that theories of development must be related to particular grammatical analyses, to particular theories about language itself [1968, p. 406].

McNeill claims that the child must acquire a generative-transformational grammar. Following N. Chomsky (1957, 1965), he asks what intrinsic properties must a device, a Language-Acquisition Device (LAD), possess to acquire such a grammar from the corpus of utterances to which it is exposed:

> LAD is, of course, a fiction. The purpose in considering it is to discuss real children, not abstract ones. We can accomplish this because LAD and children present the same problem. LAD is faced with a corpus of utterances from which it develops a grammar on the basis of some kind of internal structure. So do children. We can readily posit that children and LAD arrive at the same grammar from the same corpus, and stipulate that children and LAD therefore have the same internal structure, at least within the limits that different children may be said to have the same internal structure. Accordingly, a theory about LAD is _ipso facto_ a theory about children [1970a, p. 71].

The child must possess certain innate abilities; otherwise it is impossible to explain how the random, finite linguistic input into the child results in the output of linguistic competence.

According to McNeill, one innate property of the LAD is the ability to distinguish speech sounds from other sounds

in the environment. A second property is the ability to organize linguistic events into various classes which can later be refined. This ability allows for the development of both the phonological and syntactic systems. One of the innate organizing principles is the concept of the "sentence." A third innate property is knowledge that only a certain kind of linguistic system is possible and that other kinds are not. McNeill claims that the child is born with an innate knowledge of linguistic universals. He distinguishes (1970a) between what he calls "weak" linguistic universals (reflections in language of universal cognitive abilities) and "strong" linguistic universals (reflections in language of specific linguistic abilities). He is more interested in the latter and seems skeptical of any claims advanced by cognitive theorists about the former. A fourth property is the ability to engage in constant evaluation of the developing linguistic system so as to construct the simplest possible system out of the linguistic data that are encountered.

In an attempt to justify his position, McNeill attacks S-R theory on the grounds that language acquisition is beyond its domain:

> Because S-R theory is so limited, the problem of language acquisition simply falls beyond its domain. This in itself is not a serious matter. Not all psychological theories need account for language acquisition. More serious, however, is the fact that the application of S-R principles causes theorists to redefine language in such a way as to make the phenomenon fit the theory. There is perhaps some irony in this outcome of modern empiricism [1968, p. 412].

McNeill also argues against the importance of the frequency of stimuli in language acquisition, using examples from Japanese, and against the importance of imitation. He claims that theories requiring imitation fail to explain why only certain responses occur. He criticizes Braine for ignoring the essential transformational nature of grammatical structure. Moreover, to Lenneberg's notion of a biological foundation for language, he adds a strong cognitive "content" component in the form of a structure for the mind that allows only certain kinds of language learning to occur. The organism has the capacity to learn and to generalize, but must realize this capacity within certain innate constraints that are suggested by a particular linguistic theory.

McNeill actually says very little about the mechanisms of acquisition. In addition, his claim that in the earliest stages the child speaks in the universal base structures of a generative-transformational grammar may not be linguistically sound. His further claim that the child "honors" grammatical distinctions before actually making them has been attacked as invalid by Bloom (in press).

Cognitive Theories

Like Fodor (1966), Slobin (1966a, 1966b) does not subscribe to nativistic theories of language acquisition. He says:

> It seems to me that the child is born not with a set of linguistic categories but with some sort of process mechanism--a set of procedures and inference rules, if you will --that he uses to process linguistic data [1966b, pp. 87-88].

Slobin regards language acquisition as an active process in which certain abilities of the child develop. One is the cognitive ability to deal with the world; a second is the mental ability to retain items in short-term memory, to store items in long-term memory, and to process information increasingly with age. The developments control the pace of language acquisition. Others are important, too, such as the ability to segment utterances into sounds and meanings, and then to combine and recombine these segments, the ability to isolate meaning units, and the ability to make wide generalizations before attempting to accommodate exceptions. However, according to Slobin, general cognitive and mental development is the critical determinant of language acquisition.

Slobin marshals evidence from a variety of languages to support his position that language acquisition is one kind of general development, and that the general principles involved in the latter must be recognized. He differs from McNeill in the way he uses linguistic data. McNeill uses such data to postulate the presence of innate linguistic principles; Slobin uses the same data to support innate principles of cognition. For example, in discussing McNeill's proposal concerning the child's innate knowledge of substantive linguistic universals, Slobin says:

> Perhaps all that is needed is an ability to learn certain types of semantic or conceptual categories, the knowledge that learnable semantic criteria can be the basis for grammatical categories, and, along with this substantive knowledge, the formal knowledge that such categories can be expressed by such morphological devices as affixing, sound alternation, and so on. The child's "preprogramming" for substantive universals is probably not for specific categories like past, animate, plural, and the like, but consists rather of the ability to learn categories of a certain as-yet-unspecified type [1966b, p. 89].

Slobin differs from the behaviorist theorists in that he is a cognitive-learning theorist who regards the human learner as an active participant in learning rather than as a relatively passive reactor to external stimuli:

> The important advances in language development thus seem to be tied to such variables as increasing ability to perform a number of operations in a short time, increasing short-term memory span, and increasing cognition of the categories and processes of human experience. In fact, it may be that strictly linguistic acquisition is completed by age three or so. Further development may reflect lifting of performance restrictions and general cognitive growth, without adding anything basically new to the fundamental structures of syntactic competence. We have begun to gather data on the earliest stages of language development. We have very little data on later stages. And our understanding of the mental processes underlying the course of this development is extremely rudimentary indeed. At this point I believe we are in need of much more data on children's acquisition of various native languages . . . [1970, p. 184].

Cromer (1968) provides further evidence of the role of cognitive abilities in determining the language the child can use. From a study of the development of temporal reference in two children over a four-year period, he notes that several new types of reference to points in time begin to occur regularly at about the age of four to four and one-half for each child. Viewed together, these new forms indicate that the child has greatly expanded his range of temporal reference and increased his sense of the possible relations between times. Cromer notes that the ability develops to express events out of chronological order, to make statements about possibility, and to relate one time to another time. He hypothesizes that a single factor alone accounts for the observed linguistic changes: the child suddenly finds that he can free himself from the immediate situation and the actual order of events and can imagine himself at other points in time and view events from that perspective. This increase in his cognitive ability enables him to express new meanings, and he immediately masters the necessary syntactic apparatus to do so.

There are even stronger claims for a cognitive basis to language acquisition than those made by Slobin. Schlesinger (in press) claims that linguistic structures are ". . . determined by the innate cognitive capacity of the child," and Sinclair-de Zwart (1968) claims that "linguistic universals exist precisely because thought structures are universal." However, no empirical evidence apparently exists to confirm either claim.

Linguistically Oriented Theories Versus Learning-Oriented Theories

In trying to develop a theory of language acquisition, an investigator is faced with a fundamental decision concerning

a starting point. Should he begin by accepting certain principles from linguistics or certain principles from psychology? In other words, should be begin by saying, as McNeill does, that what must be explained is how the child acquires a generative-transformational grammar, or by saying, as Staats and Staats do, that a behavioristic theory employing such principles as association-formation and stimulus and response generalization should be able to account for language acquisition? McNeill proceeds to dismiss current learning theories as inadequate to explain the special behavior or knowledge which he claims comprises linguistic competence, and Staats and Staats proceed to ignore certain kinds of linguistic data.

Braine attempts to fasten on to the best in both linguistic theory and learning theory. He claims that each must, if necessary, be changed to accommodate the other. The two extremes of the general positions taken by McNeill and by Staats and Staats are probably equally untenable, for at one extreme the interest is basically in the linguistic description of child language with very little concern for learning principles, and at the other extreme the interest is in applying learning principles derived from experiments with animals to the one behavior that no animal exhibits, linguistic behavior. Neither McNeill nor Staats and Staats take these extreme positions, but sometimes they seem to be approaching them. In the circumstances, Braine's middle ground may appear to be more attractive; however, both linguists and learning theorists find his proposed compromises unacceptable.

Fodor acknowledges the necessity for postulating some innate structure without committing himself as to whether this structure derives from innate linguistic principles or innate learning principles:

> . . . the child must bring to the language learning situation some amount of intrinsic structure. This structure may take the form of general learning principles or it may take the form of relatively detailed and language-specific information about the kind of grammatical system that underlies natural languages. But what cannot be denied is that any organism that extrapolates from its experience does so on the basis of principles that are not themselves supplied by the experience [1966, p. 106].

Slobin's position is less equivocal. He considers the child to be endowed with the cognitive capacity to perform extremely complicated tasks. The child accomplishes the complicated task of language acquisition according to general laws of development, learning, and perception. Consequently, he brings a particular capacity to the task rather than knowledge of a set of innate linguistic principles.

Four Controversial Issues

It is of interest to examine how various theories deal with the problems of the frequency of stimuli, the place of imitation, the role of expansion, and the function of meaning in language acquisition. In this way the theories can be shown to differ in certain important respects, and some preliminary assessment can be made of their relevance to beginning reading instruction.

The relative frequency of stimuli must be important in any behavioristic theory of learning. The most frequently occurring words and structures in the language should be acquired first by the child. However, the empirical evidence for language acquisition contradicts this expectation. Telegraphic speech, for example, omits the most frequently occurring words in the language, and investigators agree that every child goes through a "telegraphic" stage. There must be some reason for the existence of such speech, but it appears to have little to do with the frequency of stimuli in the environment.

McNeill (1966, 1968) also argues that Japanese children acquire a less frequent grammatical marker <u>ga</u> before a more frequent marker <u>wa</u> because <u>ga</u> is important as a deep subject marker whereas <u>wa</u> is not. He later (1970a, pp. 30-31) offers a rather different interpretation of the same data in accordance with the kinds of predicates (intrinsic with <u>wa</u> and extrinsic with <u>ga</u>) that the child is capable of forming at the age when <u>wa</u> and <u>ga</u> first appear in speech. Slobin (in press) cites similar examples from other languages. If frequency is not important and certain kinds of learning occur in a definite progression, then the crucial issue is to account for this learning and the progression. McNeill argues that the structure of language and of the child's mind controls the learning, whereas Slobin argues that the child's cognitive and mental capacities at each stage regulate his ability to learn. However, each agrees with the other that the relative frequency of stimuli is of little importance in language acquisition.

Imitation in the sense of modeling also holds an important place in behavioristic theories of learning in which some kind of modeling of behavior must occur. While there is evidence that children do practice language (Weir, 1962) and do repeat some of the utterances of persons around them, they do not imitate indiscriminately. For example, Weir's child produced certain imitations but also made many variations on the imitated utterances. Babies do not imitate sounds in general, but they do respond quickly to human sounds. Lenneberg, Rebelsky, and Nichols (1965) also report that the prelinguistic vocalization behavior of deaf infants is no different from that of hearing infants. Therefore, imitation is not a

critical factor in this very early stage of development, as it is, for example, in Jenkins and Palermo's (1964) theory. Menyuk (1963b) notes that the ability to imitate depends on the acquisition of some prior ability since children give evidence of various difficulties in imitating utterances. Utterances such as allgone shoe, allgone lettuce, and allgone vitamins reported by Braine (1963b) also argue against imitation and for some other ability, for no such sentences occurred in the environment of the child who produced them. Similar evidence is reported by Brown and Bellugi (1964) and by Miller and Ervin (1964).

One obvious constraint upon the child's ability to imitate is the limitation imposed by his short-term memory span. It is also very difficult to explain how simple imitation leads to development. Obviously, some issue has been skirted. Young children are actually rather poor imitators, as McNeill (1966) shows in the following sample:

> The signs are that sometimes a child's tendency to assimilate adult models into his current grammar is so strong that even when he makes a deliberate effort to copy adult speech, the effort may at first fail. One child, in the phase of producing double negatives while developing the negative transformation, had the following exchange with his mother:
>
> Child: Nobody don't like me.
>
> Mother: No, say "nobody likes me."
>
> Child: Nobody don't like me.
>
> .
> .
> .
>
> [eight repetitions of this dialogue]
>
> Mother: No, now listen carefully; say "nobody likes me."
>
> Child: Oh! Nobody don't likes me.
>
> The exchange is interesting because it demonstrates the relative impenetrability of the child's grammar to adult models, even under the instruction (given by the mother's "no") to change. The child behaves at first as if he did not perceive the difference between his mother's sentence and his own, though later, when the mother supplied great emphasis, the child recognized a distinction. With this much delay in introducing changes, spontaneous imitations are bound not to be grammatically progressive because they consist only of a single exchange. The fact that a change ultimately was made, however, illustrates that children can profit from adult models [1966, p. 69].

McNeill does not deny the importance of models to the child in his learning, but does show that simple imitation of such models provides an inadequate explanation of linguistic development. Ervin (1964) demonstrates that imitations by children are not grammatically progressive, for they are less complicated syntactically than concurrent free utterances. Menyuk (1963a), Lenneberg, Nichols, and Rosenberger (1964), and Slobin and Welsh (1967) all report that children produce in imitation only what they produce in spontaneous speech even to the extent of reducing adult-given sentences to the forms they are currently producing.

Still another difficulty with relying heavily on imitation in any theory of language acquisition is the fact that much of the speech to which the child is exposed is considerably fragmented. Yet he learns to filter out poor examples in forming his grammar. This accomplishment is at least as difficult to explain as is the accomplishment of being able to react to more complex utterances than he can produce. Some factor other than imitation must be involved in each case. Lenneberg (1962) points out one specific case in which imitation could not have been involved in language acquisition, that of a boy with a congenital motor disability that prevented him from speaking. However, since the same boy could understand complicated instructions, neither imitation nor reinforcement could be used to explain his abilities. The language of the environment in which the child finds himself is vitally important to him in his acquisition of language. But direct imitation of that language seems not to occur except in rather small amounts.

The role of expansion in language acquisition is a still more complicated issue. Parents do correct and expand the speech of their children. However, there is evidence that children are not particularly receptive to direct instruction in language, as is obvious in the quotation cited above from McNeill. Although corrections might be expected to extinguish certain undesirable linguistic behaviors, they are unlikely to promote desirable ones. Expansions might be helpful in stimulating linguistic development, and some agreement exists that middle-class mothers expand their children's speech about 30% of the time and that such use of expansion forms a part of the normal mother-child relationship. Cazden (1965) tested the hypothesis that expansions of children's utterances would aid language acquisition more than would comments on their utterances, which she called models, and that both would produce better results than no expansion or modeling responses. She divided twelve 2-1/2-year-old children into three groups: the first group received intensive and deliberate expansions; the second group received qualitatively equal exposure to well-formed sentences that were models, not expansions; and the third group received no special treatment at all. Her experiment lasted twelve weeks. The results do not show

quite the expected differences; modeling, not expansion, was more effective. That is, semantically enriched responses were more effective than syntactically enriched responses. However, a more recent study by Feldman and Rodgon (1970) reports results at variance with those of Cazden. In a further study, Brown, Cazden, and Bellugi (1968) analyzed the conversations of mothers and children aged one to four years to determine what happens during such conversations. They report that the syntactic correctness or incorrectness of a child's speech does not control the mother's approval or disapproval. Rather the truth or falsity of the utterance does. They conclude that parents tend to reward true statements and punish false ones; however, somewhat surprisingly, the result is the eventual production of syntactically correct sentences.

Deliberate expansion of children's language by adults would seem to be one of the most important possible influences on language development. However, the evidence does not confirm this hypothesis. Having considered the evidence from research in the use of both imitation and expansion, Slobin (1968) concludes that there is little evidence to support imitation. However, he takes a more positive attitude toward expansion:

> It has been suggested that frequency of parental expansion of child speech may be related to such variables as social class and education, and, in turn, be partly responsible for differences in language acquisition and ability in children of different socioeconomic backgrounds. The issue is certainly complex, and we are far from being able to determine the function--if any--of expansion and imitation in the human child's remarkable acquisition of language. Until the necessary data are amassed, I would still like to believe that when a child hears an adult expansion of his own speech he learns something important about the structure of his language [1968, p. 443].

The results as a whole argue more for the acceptance of language-acquisition theories like those of Lenneberg, McNeill, and Slobin than they do for those of Braine and Staats and Staats, and more for the importance of some kind of innate linguistic or cognitive structure than of the actual stimuli encountered in the environment.

Studies of language acquisition tend to focus on the acquisition of phonology or syntax. The place and function of meaning in language acquisition have largely been ignored. However, meaning is today assuming greater importance in studies of language acquisition.

Following a comprehensive review of Russian data on language development in children, Slobin (1966a) suggests that the order of emergence of various syntactic categories depends

on their relative semantic difficulty rather than on their grammatical complexity. The first grammatical distinctions to appear are those like the singular-plural distinction that make some concrete reference to the outside world. Later to emerge are the diminutive suffixes of nouns, imperatives, and categories based on relational criteria, such as the case, tense, and person markings of verbs. Conditional forms of the if-then variety are not learned until near the end of the third year. Still other abstract categories of quality and action continue to be added until the age of seven. Slobin argues that semantic complexity rather than grammatical difficulty determines the developmental sequence. Grammatical gender in Russian is the most difficult of all the categories for the child to master since it has almost no semantic correlates. No rules exist that the child can discover to make the learning easier, so the acquisition of gender is a long, drawn-out process. Slobin (1966a) concludes: "The semantic and conceptual aspects of grammatical classes thus clearly play an important role in determining the order of their development and subdivision [p. 142]."

Telegraphic speech is full of "contentive" words. Slobin (1971, pp. 44-46) shows some of the semantic range of telegraphic speech in various languages (English, German, Russian, Finnish, Luo, and Samoan). Following an analysis of such speech, a reexamination of the data from the pivot grammars of investigators such as Braine, and some work of her own, Bloom (1970, in press) argues that the evidence indicates that semantic competence outstrips syntactic competence. Her own research showed that noun-noun combinations in the speech of very young English children expressed at least the following five relations: conjunction (block dolly), attribution (party hat), genitive (daddy hat), subject-locative (sweater chair), and subject-object (mommy book). She also found that an utterance such as no truck could have various meanings, which themselves showed an order of emergence: "nonexistence" (There's no truck here) preceding "rejection" (I don't want a truck), which in turn precedes "denial" (It's not a truck; it's something else). She concludes that the child's underlying semantic competence is more differentiated than the surface forms of his utterances, because he is aware of more types of meaning relationships than he can reveal through the linguistic devices he controls. Before he develops these devices, his two-word utterances can only be properly interpreted through the use of the nonlinguistic context. Quite often a young child must produce a series of short utterances in order to convey information that an adult or an older child expresses in a single utterance. For example, he might say raisin there / buy more grocery store / raisins / buy more grocery store / grocery store / raisin a grocery store instead of one sentence about buying more raisins at the grocery store. Consequently, Bloom (1970) claims that three components operate in the development of language competence:

cognitive-perceptual development, linguistic experience, and nonlinguistic experience. She notes that these components converge during the child's development.

An Assessment of the Theories

The studies reported by McCarthy encompass massive quantities of data but lack clearly defined theories of language acquisition. A concern for such theories is a fairly recent development in studies of language acquisition. However, all such theories have at least the weaknesses of lack of detail and lack of empirical validation. They are all very general, often being little more than series of claims about what must be, the claims being supported by reference to carefully selected data often acquired from no more than a few children. Consequently, they are often hardly any more convincing than former presentations of large quantities of data that really make no claims at all.

Recently proposed theories make either a language or learning component central. Making a language component central requires postulation of a strong innate predisposition toward the acquisition of very specific kinds of linguistic facts, for the child is assumed to "know" much about language in general before any learning of specific details begins. Environmental factors are relatively unimportant in such theories. On the other hand, older behavioristic learning theories hold the environment to be extremely important in providing language stimuli and controlling the learning that occurs. According to such theories, language acquisition is achieved through such processes as association and response generalization. The child makes little or no active contribution to the total process and learns language in much the same way as he learns anything else.

A less extreme position is that language acquisition is unique because language is different from anything else that is learned, but that the learning requires use of many of the same principles as other kinds of learning. In this case, the theory may have a large biological component that emphasizes the importance of certain kinds of universal neurological and physiological developments. Or it may assume the availability of this component and emphasize the kinds of meaningful situations that stimulate language acquisition and the cognitive limitations that human development places on the acquisition process. Unfortunately, since meaning has long been a stepchild in linguistics and cognitive theory a poor relation in psychology, it is difficult at present to fill out the details of any such theory.

An evaluation of the importance of such factors as frequency, imitation, and expansion in language acquisition

leads to the rejection of any kind of monolithic behavioristic theory. However, it does not eliminate linguistically based theories nor does it contradict cognitively based ones. The evaluation reveals how unimportant each of the factors is in language acquisition, and indicates the necessity of crediting the child with some kind of innate knowledge or capacity. The difficulty with the innate-knowledge hypothesis is that investigators like McNeill have very little to say about the mechanisms through which that knowledge reveals itself, nor do they try to relate language learning to other kinds of learning. The result is something less than a parsimonious view of total human development. The advantage of the innate-capacity hypothesis is that general laws of learning, but not exclusively behavioristic ones, can be used to explain both language acquisition and other kinds of learning. Sachs (1971) summarizes this problem as follows:

> Theories of language acquisition that consider only the linguistic aspect will not be able to explain why the child learns new forms when he does, or in fact why he ever changes his form of expression. It is only through more research on the complex relationship between cognitive development and language acquisition that we will have a full understanding of either. Hopefully in the future we will find more studies of this type, and a closer communication between psycholinguists and psychologists studying other aspects of child development.

The linguistically based theories all have one serious drawback in that they are concerned with the ideal child. Theories recognizing individual and group differences are ignored in favor of theories that try to account for the development of abstract linguistic competence. Social, motivational, and cultural variables are all ignored. The child is said to have acquired his basic linguistic competence by the age of five or six. While performance is acknowledged to vary from child to child, such variability, whatever its cause, is ignored, often under the guise of "performance" differences, which are at best of peripheral interest. The result is a deliberate biasing of the theories toward accommodating one set of factors in language acquisition and ignoring almost all others.

LANGUAGE ACQUISITION AND BEGINNING READING

Language Acquisition After Age Six

Although many linguists claim that the major part of language acquisition takes place in the years between the ages of one and four, children who enter school do not have the linguistic abilities of adults. Furthermore, the linguistic abilities of adults change, and sometimes develop, during

their lives. It is of interest to know the precise differences between the linguistic abilities of children entering school and of adults. Numerous investigators have shown that significant language development still occurs in all children after the age of five or six, among them Harrell (1957), Strickland (1962), Loban (1963), Menyuk (1963b), and O'Donnell, Griffin, and Norris (1967).

In a recent study, C. S. Chomsky (1969) points out several grammatical developments that occur during the years that follow six: a grasp of the difference between the eager to see and easy to see constructions; a realization that ask and tell require different syntactic constructions; the ability to handle relationship requiring and and although; and a control of pronominalizations. Kessel (1970) used a Piaget-type interview technique similar to that used by C. S. Chomsky in further work on some of the same problems. His study confirms her results but also reports evidence of a somewhat earlier mastery of the more complex constructions. Menyuk (1969) points out other examples in which a more complicated structure is learned later than a less complicated one. However, in every case it is possible to argue that the linguistic development has not occurred because the cognitive capacities of the child did not allow it rather than because the structure which is learned second is more complicated than the one which is learned first. Of course, since it is also possible to argue that the structure learned second is grammatically more complicated, the temptation is to postulate a linguistic rather than a cognitive constraint on development, particularly when the investigator is linguistically oriented.

Two linguistic abilities that children of about age six appear to have are those to overdiscriminate and to overgeneralize. N. Chomsky (1964) points out that they have very sharp abilities to discriminate among phonetically close stimuli. Ervin (1964) and Miller and Ervin (1964) say that they tend to eliminate from their language irregular but correct inflections in favor of regular but incorrect ones for a while. Slobin (1970a), citing evidence mainly from Russian, discusses this same phenomenon, which he calls "inflectional imperialism." Bever, Mehler, and Valian (1968) report that children aged two to four temporarily overgeneralize newly acquired semantic strategies. There is also some agreement that children do not interpret "same" and "different" in the way that mature adults do, nor are they able to work in a conscious analytic fashion with language, as many adults can. Slobin (1970a) points out that the Russian data he analyzed provide evidence that any kind of direct instruction in the analysis of language is rather ineffective with children.

In one crucial area for any kind of reading instruction that relies on the relationship of individual sounds to symbols, the acquisition of phonology, six-year-olds have not

mastered the system that educated literate adults appear to have mastered (Chomsky & Halle, 1968; C. S. Chomsky, 1970). The abilities of the two groups appear to be quite different. Indeed language acquisition in this area appears to depend on the acquisition of the ability to read, but this is the only place where this particular dependency occurs.

Some Important Differences Between Language Acquisition and Beginning Reading

Whatever theory of language acquisition an investigator subscribes to, behavioristic, nativistic, or cognitive, he must readily admit that important differences exist between the acquisition of language and the acquisition of beginning reading skills. Staats and Staats (1962), Carroll (1966), and Natchez (1967) are among those who point out some of the specific differences.

Language is acquired gradually and the acquisition process is probably never completed, for something always remains to be learned. The process is also one that had no conscious beginning point for the child. On the other hand, learning to read often has a sudden onset for children, although some are fortunate to avoid this kind of introduction. Even though some of the cognitive and motor skills necessary for reading have been developed for other activities, the child is often required to put them all together rather abruptly in learning to read in a formal school setting.

The level of anxiety in the context in which learning to read takes place may also be quite high: the anxiety of the parent, teacher, and the child. Little such anxiety is manifested during the process of learning to talk. Certainly, it is the rare child who exhibits anxiety, and, if the occasional parent is anxious about a particular child's speech, this anxiety seems to have little influence on the child's language development. There is also often a concomitant assignment of blame for any "failure" that occurs in beginning reading instruction. Children are not "blamed" when they fail to acquire language; rather, they are given special help.

Reading instruction is very formal and deliberate. Language, however, is learned informally and unconsciously from a wide range of stimuli. No deliberate instruction is necessary. Language is not learned from programmed stimuli, from making conscious distinctions among stimuli, from learning "about" language, and from acquiring control of a variety of analytic and synthetic techniques. While controversy does exist as to the function of linguistic stimuli in language acquisition, there is agreement that such stimuli vary in both form and content in ways that are not well understood, but which the child is well able to handle.

The usual reinforcements experienced by literate adults for reading may be irrelevant for many children in the beginning reading stages: the benefits are often too abstract, distant, and meaningless, and the effort to be expended for such remote ends may seem to be quite wasteful and unpleasant to the child. On the other hand, the benefits of learning to speak are too obvious to mention.

The two activities are also different in certain other ways. Learning to read depends on the acquisition of special skills in visual discrimination. The redundancies in the two language systems that are involved are also different, as is quite often the content (that is, the meanings) that are conveyed. Writing is not simply speech written down: it is more abstract than speech in content; it usually employs carefully edited and controlled language for reasons different from speaking; and it functions rather differently in the lives of the recipients of the message. Vygotsky (1962) writes as follows on these very points, but in connection with writing rather than reading:

> Written speech is a separate linguistic function, differing from oral speech in both structure and mode of functioning. Even its minimal development requires a high level of abstraction. . . . Our studies show that it is the abstract quality of written language that is the main stumbling block, not the underdevelopment of small muscles or any other mechanical obstacles.
>
> Writing is also speech without an interlocutor, addressed to an absent or an imaginary person or to no one in particular--a situation new and strange to the child. Our studies show that he has little motivation to learn writing when we begin to teach it. He feels no need for it and has only a vague idea of its usefulness. In conversation, every sentence is prompted by a motive. Desire or need lead to request, question to answer, bewilderment to explanation. The changing motives of the interlocutors determine at every moment the turn oral speech will take. It does not have to be consciously directed--the dynamic situation takes care of that. The motives for writing are more abstract, more intellectualized, further removed from immediate needs. In written speech, we are obliged to create the situation, to represent it to ourselves. This demands detachment from the actual situation.
>
> Writing also requires deliberate analytical action on the part of the child. In speaking, he is hardly conscious of the sounds he pronounces and quite unconscious of the mental operations he performs. In writing, he must take cognizance of the sound structure of each word, dissect it, and reproduce it in alphabetical symbols which he must have studied and memorized before [1962, pp. 98-99].

Reid (1966), Meltzer and Herse (1969), and Downing (1970) all point to the confusion that children often experience in

learning to read. Evidently, many children do not understand what reading is, or what they are supposed to be doing, or what the terms mean that are used in the instructional process.

The usual methods of reading instruction employ imitation, repetition, control of stimuli, correction, and expansion--exactly those factors examined earlier in relation to the acquisition of language. These factors were found not to be very important in language acquisition; however, they are very important in reading instruction. Of course, instruction implies some kind of methodology, so the reason for their existence is obvious. Yet, it would be well to subject that methodology to periodic critical assessment in the light of the latest findings from relevant disciplines. Of course, one can also argue that since language acquisition and learning to read are quite different tasks, these factors may still be important in the teaching of beginning reading.

Finally, language acquisition does not cease at age six. Consequently, some kinds of acquisition overlap with learning to read. However, little is known about the extent of this overlap, for the later stages of language acquisition are even more of a mystery than are the earlier stages. It may be that more than one of these stages depends on the child's acquiring certain reading abilities just as beginning reading ability quite definitely depends on the acquisition of considerable linguistic competence. However, this acquisition has occurred in six-year-olds except in rare pathological cases.

CONCLUSION

The theories of language acquisition that are available to us today are largely irrelevant in deciding issues in beginning reading instruction or even in devising models of the reading process. Moreover, reading failure cannot easily be linked to deficiencies in language acquisition, for children who are asked to learn to read are almost invariably well on the way to linguistic maturity.

Reading methods themselves are almost unrelated to theories of language acquisition. Both phonics and whole-word methods depend on the possession of certain language abilities which all children of six apparently have. What they might not have are some of the cognitive abilities that the methods require: abilities to make certain kinds of discriminations, to form generalizations, and to verbalize knowledge. Furthermore, much of what is taught "about" language in such methods is antiquated and not very useful to anyone, particularly to six-year-olds.

Reading is often taught to improve language. Research has long demonstrated that such teaching is generally

ineffective. Some linguistic skills apparently derive from the acquisition of the skills of literacy, but these skills appear to be few and certainly do not seem to be acquired during the critical period of beginning reading instruction.

REFERENCES

Bever, T. G., Fodor, J. A., & Weksel, W. Is linguistics empirical? Psychological Review, 1965, 72, 492-500. (a)

Bever, T. G., Fodor, J. A., & Weksel, W. On the acquisition of syntax: A critique of "Contextual generalization." Psychological Review, 1965, 72, 467-482. (b)

Bever, T. G., Mehler, J. R., & Valian, V. V. Linguistic capacity of very young children. Unpublished manuscript, ERIC ED 018-796, 1968.

Bloom, L. Language development: Form and function in emerging grammars. Cambridge, Mass.: M.I.T. Press, 1970.

Bloom, L. Why not pivot grammar? The Journal of Speech and Hearing Disorders, in press.

Braine, M. D. S. On learning the grammatical order of words. Psychological Review, 1963, 70, 323-348. (a)

Braine, M. D. S. The ontogeny of English phrase structure: The first phase. Language, 1963, 39, 1-13. (b)

Braine, M. D. S. On the basis of phrase structure: A reply to Bever, Fodor, and Weksel. Psychological Review, 1965, 72, 483-492.

Brown, R. Social psychology. New York: Free Press, 1965.

Brown, R., & Bellugi, U. Three processes in the child's acquisition of syntax. Harvard Educational Review, 1964, 34, 133-151.

Brown, R., & Berko, J. Psycholinguistic research methods. In P. H. Mussen (Ed.), Handbook of research methods in child development. New York: Wiley, 1960.

Brown, R., Cazden, C. B., & Bellugi, U. The child's grammar from I to III. In J. P. Hill (Ed.), The 1967 Minnesota symposium on child psychology. Minneapolis: University of Minnesota Press, 1968.

Carroll, J. B. Language development in children. In Encyclopedia of educational research. New York: Macmillan, 1960. Pp. 744-750.

Carroll, J. B. Some neglected relationships in reading and language learning. Elementary English, 1966, 43, 577-582.

Cazden, C. B. Environmental assistance to the child's acquisition of grammar. Unpublished doctoral dissertation, Harvard University, 1965.

Chomsky, C. S. The acquisition of syntax in children from 5 to 10. Cambridge, Mass.: M.I.T. Press, 1969.

Chomsky, C. S. Reading, writing, and phonology. Harvard Educational Review, 1970, 40, 287-309.

Chomsky, N. Syntactic structures. The Hague: Mouton, 1957.

Chomsky, N. Review of B. F. Skinner, Verbal behavior. Language, 1959, 35, 26-58.

Chomsky, N. Comments for project literacy meeting. Project Literacy Reports, 1964, 2, 1-8.

Chomsky, N. Aspects of the theory of syntax. Cambridge, Mass.: M.I.T. Press, 1965.

Chomsky, N., & Halle, M. The sound pattern of English. New York: Harper & Row, 1968.

Cromer, R. The development of temporal references during the acquisition of language. Unpublished doctoral dissertation, Harvard University, 1968.

Downing, J. The development of linguistic concepts in children's thinking. Research in the Teaching of English, 1970, 4, 5-19.

Elkonin, D. B. Razvitie rechi v doshkol'nom vozraste (The development of speech in preschool age). Moscow: Akad. Pedag, Nauk RSFSR, 1958.

Ervin, S. M. Imitation and the structural change in children's language. In E. H. Lenneberg (Ed.), New directions in the study of language. Cambridge, Mass.: M.I.T. Press, 1964.

Ervin-Tripp, S. M. Language development. In M. Hoffman & L. Hoffman (Eds.), Review of child development research, 2. Ann Arbor: University of Michigan Press, 1966.

Ervin-Tripp, S. M., & Slobin, D. I. Psycholinguistics. Annual Review of Psychology, 1966, 17, 435-474.

Feldman, C. F., & Rodgon, M. The effects of various types of adult responses in the syntactic acquisition of two- to

three-year-olds. Unpublished paper, Department of Psychology, University of Chicago, 1970.

Fodor, J. A. How to learn to talk: Some simple ways. In F. Smith & G. A. Miller (Eds.), The genesis of language: A psycholinguistic approach. Cambridge, Mass.: M.I.T. Press, 1966.

Garrett, M., & Fodor, J. A. Psychological theories and linguistic constructs. In T. R. Dixon & D. L. Horton (Eds.), Verbal behavior and general behavior theory. Englewood Cliffs, N. J.: Prentice-Hall, 1968.

Harrell, L. E., Jr. An inter-comparison of the quality and rate of the development of the oral and written language in children. Monographs of the Society for Research in Child Development, 1957, 22.

Jenkins, J., & Palermo, D. Mediation processes and the acquisition of linguistic structure. In U. Bellugi & R. W. Brown (Eds.), The acquisition of language. Monographs of the Society for Research in Child Development, 1964, 29 (1, Serial No. 92).

Kelley, K. L. Early syntactic acquisition. Santa Monica, Calif.: Rand Corporation, 1967.

Kessel, F. S. The role of syntax in children's comprehension from ages six to twelve. Monographs of the Society for Research in Child Development, 1970, 35, No. 6 (Whole No. 139).

Klima, E. S., & Bellugi, U. Syntactic regularities in the speech of children. In J. Lyons & R. Wales (Eds.), Psycholinguistic papers. Edinburgh: Edinburgh University Press, 1966.

Lenneberg, E. H. Understanding language without the ability to speak: A case report. Journal of Abnormal Social Psychology, 1962, 65, 419-425.

Lenneberg, E. H. Biological foundations of language. New York: Wiley, 1967.

Lenneberg, E. H., Nichols, I. A., & Rosenberger, E. F. Primitive stages of language development in mongolism. Proceedings of the Association for Research on Nervous and Mental Disease, 1964, 42, 119-137.

Lenneberg, E. H., Rebelsky, F. G., & Nichols, I. A. The vocalization of infants born to deaf and to hearing parents. Vita Humana, 1965, 8, 23-37.

Loban, W. D. The language of elementary school children. Champaign, Ill.: National Council of Teachers of English, 1963.

McCarthy, D. Language development in children. In L. Carmichael (Ed.), Manual of child psychology. New York: Wiley, 1954.

McNeill, D. Developmental psycholinguistics. In F. Smith & G. A. Miller (Eds.), The genesis of language: A psycholinguistic approach. Cambridge, Mass.: M.I.T. Press, 1966.

McNeill, D. On the theories of language acquisition. In T. R. Dixon & D. L. Horton (Eds.), Verbal behavior and general behavior theory. Englewood Cliffs, N. J.: Prentice-Hall, 1968.

McNeill, D. The acquisition of language: The study of developmental psycholinguistics. New York: Harper & Row, 1970. (a)

McNeill, D. The development of language. In P. A. Mussen (Ed.), Carmichael's manual of child psychology. New York: Wiley, 1970. (b)

Meltzer, N. S., & Herse, R. The boundaries of written words as seen by first graders. Journal of Reading Behavior, 1969, 1, 3-13.

Menyuk, P. A preliminary evaluation of grammatical capacity in children. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 429-439. (a)

Menyuk, P. Syntactic structures in the language of children. Child Development, 1963, 34, 407-422. (b)

Menyuk, P. Sentences children use. Cambridge, Mass.: M.I.T. Press, 1969.

Miller, W., & Ervin, S. M. The development of grammar in child language. In U. Bellugi & R. Brown (Eds.), The acquisition of language. Monographs of the Society for Research in Child Development, 1964, 29 (1, Serial No. 92).

Natchez, G. From talking to reading without really trying. The Reading Teacher, 1967, 20, 339-342.

O'Donnell, R. C., Griffin, W. J., & Norris, R. C. Syntax of kindergarten and elementary school children: A transformational analysis. Champaign, Ill.: National Council of Teachers of English, 1967.

Reid, J. F. Learning to think about reading. Educational Research, 1966, 9, 56-62.

Sachs, J. The status of developmental studies of language. In J. Eliot (Ed.), Human development and cognitive processes. New York: Holt, Rinehart, & Winston, 1971.

Schlesinger, I. M. Production of utterance and language acquisition. In D. I. Slobin (Ed.), The ontogenesis of grammar: Facts and theories. New York: Academic Press, in press.

Sinclair-de Zwart, H. Sensorimotor action schemes as a condition of the acquisition of syntax. Unpublished paper, University of Geneva, 1968.

Slobin, D. I. The acquisition of Russian as a native language. In F. Smith & G. A. Miller (Eds.), The genesis of language: A psycholinguistic approach. Cambridge, Mass.: M.I.T. Press, 1966. (a)

Slobin, D. I. Comments on "Developmental psycholinguistics." In F. Smith & G. A. Miller (Eds.), The genesis of language: A psycholinguistic approach. Cambridge, Mass.: M.I.T. Press, 1966. (b)

Slobin, D. I. Imitation and grammatical development. In N. S. Endler, L. R. Boulter, & H. Osser (Eds.), Contemporary issues in developmental psychology. New York: Holt, Rinehart, & Winston, 1968.

Slobin, D. I. Early grammatical development in several languages, with special attention to Soviet research. In T. G. Bever & W. Weksel (Eds.), The structure and psychology of language. New York: Holt, Rinehart, & Winston, 1970. (a)

Slobin, D. I. Universals of grammatical development in children. In G. B. Flores d'Arcais & W. J. M. Levelt (Eds.), Advances in psycholinguistics. Amsterdam: North Holland Publishing Company, 1970. (b)

Slobin, D. I. Psycholinguistics. Glenview, Ill.: Scott, Foresman, 1971.

Slobin, D. I., & Welsh, C. A. Elicited imitation as a research tool in developmental psycholinguistics. Unpublished paper, Department of Psychology, University of California, Berkeley, 1967.

Staats, A. W., & Staats, C. K. A comparison of the development of speech and reading behavior with implications for research. Child Development, 1962, 33, 831-846.

Staats, A. W., & Staats, C. K. _Complex human behavior: A systematic extension of learning principles_. New York: Holt, Rinehart, & Winston, 1963.

Staats, A. W., & Staats, C. K. _Language, learning, and cognition_. New York: Holt, Rinehart, & Winston, 1968.

Strickland, R. G. The language of elementary school children: Its relationship to the language of reading textbooks and the quality of reading of selected children. _Bulletin of the School of Education_, 1962, 38, Bloomington: Indiana University.

Vygotsky, L. S. _Thought and language_. Cambridge, Mass.: M.I.T. Press, 1962.

Weir, R. _Language in the crib_. The Hague: Mouton, 1962.

Weksel, W. Review of U. Bellugi and R. Brown (Eds.), _The acquisition of language_. _Language_, 1965, 41, 692-709.

SECTION 7

PAPERS ON LEARNING TO READ

LEARNING TO READ: AN OPERANT PERSPECTIVE

Richard D. Bloom

State University of New York at Stony Brook

It is the position of this report that operant-learning concepts can provide fruitful insights into reading behavior. More particularly, the thrust of this report will be an examination of the process of learning to read and the design of instructional paradigms for teaching reading as viewed from an operant-learning perspective.

A major objective of an operant analysis is the specification and description of environmental variables which are capable of modifying and controlling a particular category of behavior. Accordingly, attention first needs to be directed to an identification and elaboration of major operant parameters and a consideration of the possible impact of these variables on learning to read.

One major operant parameter involves the stimulus control of reading behavior. An important class of such stimulus events obviously arises from the physical environment as setting the occasion for a particular verbal response. For instance, Skinner (1957) refers to a "tact" as a speech response (i.e., naming and labeling) made to an environmental event as when a child says "ball" when he encounters this object in his environment. Similarly, the term "text" refers to a reading response made to a textual stimulus ranging from a specific letter or phoneme to a word. Thus, from an operant standpoint an important component in learning to read is the attachment of a reading response to a particular textual cue. The strengthening of this association occurs via the mechanism of reinforcement, which will be subsequently discussed.

The interest in stimulus-control factors is not limited to an operant analysis. For instance, Gibson, Pick, Osser, and Hammond (1962) clearly emphasize within their cognitive model of reading that one early phase of reading acquisition involves the learning of distinctive features of letters through the process of perceptual comparison and scanning. Similarly, many of the current approaches to teaching early reading skills focus on the problem of cueing a reading response from a written symbol. Perhaps the best example of this concern involves the development of the initial-teaching alphabet (i.t.a.). Briefly, i.t.a. is an attempt

to redesign the alphabet so that there is a greater proportion of one-letter one-sound S-R mechanisms, thereby minimizing response confusion resulting from the potential capacity of a letter to cue off more than one phonetic response. Needless to say, i.t.a. has generated many controversial issues and research findings which, though interesting and lively, are beyond the scope of this paper.

A second operant parameter dealing with reading behavior involves the reinforcement process. That is, a given behavior produces some environmental consequence. In turn, this consequence, called a reinforcing event, exerts a strengthening and maintaining effect upon that behavior. Operationally, strengthening would refer to an observed change in the frequency of a behavior relative to a base period of nonreinforcement of the response in question. Considerable research, for example that of Skinner (1938), has demonstrated such strengthening effects, especially under conditions in which a precise contingency relation is established between a behavior and some environmental event.

On a conceptual level, reinforcement has been criticized because it appears to be only a circular definition rather than a scientific law. That is, the concept of a reinforcing event appears to lack an independent status since its operational definition depends on whether or not a response preceding the reinforcement is strengthened. One strategy by which this conceptual dilemma may be resolved involves the empirical demonstration (Premack, 1965) that a reinforcing event has transituation properties; i.e., the capacity to strengthen more than one kind of response.

There are alternative avenues by which reinforcement may influence verbal behavior. One possibility is that, through association with an established reinforcer, a neutral event may also acquire a strengthening potential on verbal behavior. Thus, Staats, Minke, Finley, and Brooks (1964b) have presented evidence that a token reinforcement system (i.e., tokens which have been associated with already established reinforcers, such as money, candy, or toys) may be used in teaching reading skills. One especially important class of acquired or secondary reinforcers of verbal behavior consists of a wide range of others' evaluative comments (e.g., "That's good." "You are wrong," etc.) directed at a person's behavior. Krasner's (1958) review of the literature has shown that such evaluative comments may exercise generally consistent strengthening effects on categories of verbal responses. In the context of reading instruction, the teacher's feedback comments directed toward a pupil's effort at reading may also be subsumed within this category of evaluative reinforcement.

The possibility also exists that reinforcement for verbal behavior may not only be mediated on an interpersonal

but also on an intrapersonal level. In the latter case, attention is directed to the mechanism of self or intrinsic reinforcement (e.g., saying, "That's right" to oneself) contingent upon a particular verbal response emitted by the individual. Similarly, the inexperienced reader may reinforce himself for tentative pronunciations of unfamiliar words embedded as part of some text material. Also included in this category is the possibility that an activity, such as reading, becomes self-reinforcing as a result of its attractiveness or value to the individual. The basis by which an intrinsic or self-reinforcement system is acquired will be considered in a subsequent section of this paper.

The parameters of stimulus control and reinforcement constitute the major functional influences on speech and reading behavior. Everything considered, these basic explanatory mechanisms appear very meager relative to the complexities of verbal behavior. However, the power of a single variable may be considerably expanded when an assumption is made of interactions between and within operant parameters. For example, in addition to particular letters and words acting as controlling stimuli for reading, the individual's reading activities might also be influenced by internally produced cues. Thus, Rothkopf (1966, 1970) postulates that over and beyond the nominal stimuli (which correspond to the letter configurations of some text material) there are effective stimuli. The latter refer to the psychological consequences of nominal stimuli which, accordingly, cannot be directly observed. Rothkopf would argue that it is the effective stimuli which control behaviors involved in the internal processing of information --e.g., rehearsal and problem-solving activities associated with reading a text passage. The inclusion within an operant framework of such inferred stimulus and behavioral events can be justified if it can be demonstrated that environmental variables may be manipulated to influence unobservable reading activities. For instance, Frase (1970), Rothkopf (1966), and Hershberger and Terry (1965) have shown that questions embedded as part of some text material may exercise considerable control over the amount and kinds of text-related information which is retained on a short- and long-term retention basis.

So much for the brief theoretical account of operant variables in relation to reading. It is now appropriate to detail some of the implications of this discussion--particularly the reinforcement parameter--for reading instruction.

First, since operant-learning strategies require an explicit identification of response-reinforcement contingencies, consideration must be given to the definition of the response units to be strengthened. In the case of laboratory research, the well-known bar press response represents a discrete and readily quantifiable bit of behavior. In contrast,

reading does not possess such easily identifiable characteristics. Rather, it might better be characterized as composed of a number of different but related behavioral domains ranging from those which are readily observable (e.g., attention, eye fixation) to those which are unobservable and therefore by necessity, inferential. Included in the latter might be such activities as the translation of printed symbols into cognitive representations, comprehension, and inferential skills.

To illustrate the utilization of reinforcement contingencies, it might be assumed that maintaining attention toward the printed page would be an important prerequisite to the establishment of adequate reading performance. For example, in some of the instructional research reported by Staats and Butterfield (1965), provisions are made for the consistent reinforcement of attending to the printed page whenever this behavior occurs within the boundaries of defined time segments. There is, of course, the danger of reinforcing only attention since a child may learn to look at a page but not ever read it. Accordingly, in addition to strengthening attentional skills, deeper reading skills involving comprehension or understanding need to be acquired and maintained. Thus, reinforcement contingencies might be specified for observable indices or manifestations of reading comprehension; e.g., the token reinforcement of correct answers to questions assessing reading comprehension.

Second, the application of operant concepts involves the utilization of those categories of reinforcing events which are likely to optimize a student's learning and motivational status during reading instruction. There is undoubtedly an enormous array of environmental features--ranging from activities, tangibles, and evaluative reactions of others--which might serve as potentially effective reinforcers of reading behavior. However, based on Premack's (1959) analysis, the effectiveness of a given reinforcing event may vary from individual to individual, depending on its relative subjective attractiveness or value.

It is argued that the use of environmentally attractive features as reinforcers, when made accessible to the learner, contingent upon the occurrence of specific reading behavior, will provide a powerful basis for particularly establishing and motivating early reading efforts. The importance of this point arises from a body of research literature and theoretical analyses which strongly indicates that the sources of reinforcement which are frequently depended upon in typical instructional situations are far from adequate in supporting the reading behaviors of many learners. For example, Staats (1968) has hypothesized that the kinds of socialization experiences of children will determine their responsiveness to intrinsically oriented reinforcement based upon knowledge of being correct. In expanding upon this hypothesis,

Staats suggests that a reinforcement system based on informational feedback will develop only if a child has been consistently and vigorously rewarded for behavior which matches against some adult standard or model. It may thus be presumed that children who are deficient in such social training will frequently find the conditions of classroom reinforcement--which frequently emphasize the importance of being correct--as not an especially potent goad to learning. Such a hypothesis may account for the findings reported by Rosen (1956), Terrell, Durkin, and Wiesley (1959), and Zigler and Kanger (1962) that intrinsic reinforcement (defined as knowledge of being correct) is relatively weak in comparison to tangible reinforcement in facilitating the learning of socially disadvantaged children.

Staats and Staats (1962a) characterize the process of learning to read, in contrast to learning to speak, as often representing a very abrupt and concentrated instructional experience. Further, the fact that reading instruction frequently occurs within the context of a classroom involving many children militates against the application of reinforcement being promptly and consistently made contingent upon the numerous reading responses of a particular pupil. Then, too, the extensive dependence upon grades as a reward for school learning is probably an inadequate reinforcement for many children, especially because it represents a global nonspecific feedback mechanism which, by its very nature, must be delayed considerably after a pupil's many learning efforts. Thus, the conditions of an intensive learning experience in relation to inadequate reinforcement conditions may cause many children to experience reading instruction as aversive. Indeed, the aversive properties, which have been characterized in reading instruction, may interfere with the establishment of an intrinsic reinforcement system for reading in which this activity acquires positive attractiveness for the individual.

Overall, then, as a result of an individual's past learning history or his present instructional milieu, or both, the conditions of reinforcement are hypothesized as often inadequate as a basis for acquiring and maintaining reading skills. In either case, the instructional arrangements need to be altered so as to provide the kinds of reinforcement for reading toward which the learner may become more responsive.

A third consideration in the application of operant principles involves the gradual shaping of reading behavior in the direction of increasingly complex activities. While the idea of progressing from simple to complex reading skills is not novel, operant analyses require the reading specialist to become very explicit regarding the importance of sequencing reading instruction. As Gagné (1970) suggests, learning to read involves the acquisition of a hierarchy of increasingly

complex reading skills.* Further, if reading is to occur at one level of the hierarchy, careful attention needs to be given to the mastery of lower-level prerequisite skills. Accordingly, a careful task analysis of the kind Gagné suggests is required to identify those reading skills which appear to contribute to terminal reading performance. In turn, such component reading skills can serve as the focus of reading instruction involving the application of consistent and adequate reinforcement contingencies by which these behaviors may be gradually strengthened.

Finally, the utilization of an operant instructional framework has the potential for providing a "fine-grained" quantifiable analysis of the course of reading acquisition. This comes about because emphasis is placed on an objective definition of response units which are to be reinforced. Since the frequency of such response units becomes a major operant datum, it becomes possible to formulate varied indices of reading behavior such as the number of responses per time unit, number of correct responses per training session, or cumulative response curves. Further, the fact that considerable response data can be collected from a single learner enables the researcher to carry out reliable operant investigations of reading with limited numbers of subjects.

The discussion above has been admittedly speculative. Attention needs to be given to a brief review of research dealing with the application of operant variables to reading instruction. A substantial amount of research in this area has been conducted by Staats and his associates (1962b, 1964a, 1964b, 1965), using token procedures. Specifically, tokens (functioning as acquired reinforcers) are presented contingent upon the occurrence of appropriate reading responses. Typically, a schedule of reinforcement is used such that a fixed number of responses must occur before a token is earned. In turn, the tokens can be exchanged for attractive objects serving as back-up reinforcers. Token arrangements have been adopted for use with such reading materials as flash cards requiring the recognition of phonemes, letters, words, larger units consisting of single sentences or paragraphs. Since the back-up reinforcers are not presented on a continuous basis, the chances that the learner will develop a rapid satiation or indifference to them are probably minimized. The following are basic conclusions which may be gleaned from this research:

1. Token reinforcement procedures appear applicable to a wide range of children varying in ages (from preschoolers to

---

*Gagné (1970, pp. 270-272) specifies a nine-level hierarchy of reading skills which begins with the ability to reproduce single letter sounds and to reproduce sounds from printed letters, and ends with the ability to read words orally according to rules of pronunciation.

adolescents), IQ (from retardates to bright normals), and social-class status. Evidence further indicates that, using operant reinforcement procedures, children evince involvement and interest in the reading activities which can be maintained over several training sessions. The only qualification to this conclusion is that if responsiveness to the training program is to be sustained, it is often necessary to provide more frequent reinforcement of reading responses, particularly at the early stages of instruction, where presumably greater cognitive effort is required. Once the learner has achieved some mastery of basic skills, the ratio of responses to reinforcement can generally be increased.

2. It is evident that children can learn to read under operant instructional arrangements. Using operant procedures, the reading acquisition progresses slowly at first but then rapidly accelerates as a function of training sessions (Staats, 1968). However, it is not possible to say that operant procedures are either superior or inferior to alternative approaches to reading with respect to such skills as word recognition and comprehension. This, of course, reflects the fact that there have been no direct comparisons between instructional programs which have explicitly incorporated operant strategies and other instructional programs.

3. The investigations of operant applications in reading have typically been descriptive of the methodology, providing only normative data regarding the course of reading acquisition. There have been a few investigations, for example Staats et al. (1962, 1964a), in which operant variables have been experimentally manipulated. The effects of such manipulations on reading behavior have been generally consistent with behavioral outcomes obtained within a laboratory setting. For example, under conditions of withdrawal of tokens after consistent reinforcement, there tends to be a marked reduction in reading activity. This closely parallels the phenomenon of extinction in which behavioral output can be drastically reduced subsequent to the termination of reinforcement.

Perhaps the most frequently researched area within an operant framework involves the effects of intermittent schedules of reinforcers on performance. Typically, when reinforcement is presented on an irregular basis (i.e., not all responses are reinforced), performance curves are found to be higher than under conditions in which reinforcement is presented contingent upon the occurrence of each response. Staats et al. (1962) have observed a parallel finding with reading behavior. That is, when an experimental group is provided intermittent randomized reinforcement, reading performance (defined as the number of correct letter or word recognitions) is elevated in comparison to a base-line period involving continuous reinforcement. Such research as this can

provide important cues to the optimum motivation of reading activity in relation to a minimum expenditure of reinforcement.

4. The investigations described so far have utilized tangible reinforcers in conjunction with reading instruction. An exception to this pattern may be noted in the following summarized research. Raygor (1966) attempted to increase reading speed by flashing a green light (serving as a secondary reinforcer) whenever a subject exceeded his previous reading rate. The research showed that reading rate accelerated, especially under those experimental conditions in which the function of the flashing light was explained to the subject. Smith (1969) also investigated the effectiveness of knowledge of results as a secondary reinforcement for reading behavior in elementary-school children. In this study, the number of correct reading responses (involving both word recognition and comprehension) was determined after each instructional session, and then plotted by the children in the form of a work progress chart. The findings showed that the response output of children working under the conditions of knowledge of results was considerably higher than the output of the children working under alternative reinforcement conditions of teacher praise and work breaks contingent upon correct performance. Of particular significance was that the performance of the group working under conditions of knowledge of results equaled that of a group of subjects who received small amounts of money as reinforcement for appropriate reading behavior. Evidently, under certain instructional arrangements, informational feedback can exercise strong motivational effects approximating those of a presumably powerful reinforcer --money.

The review of literature just completed has focused on the application of reinforcement strategies to reading instruction. There are, however, some basic research questions which need to be tested to achieve a satisfactory evaluation of operant applications. In particular, the following research issues are suggested:

1. Earlier, it was suggested that reading may be characterized as a multilevel process ranging from overt molar activities to unobservable (deep-processing) behavior. It would be important to determine the extent to which operant techniques may be used to shape or influence various components of the reading process. There is evidence, which has been collected within school situations (Hall, Lund, & Jackson, 1968; O'Leary, 1968), that maintaining attention to studying activities can be shaped through reinforcement strategies. But while these data are available, there is surprisingly little clear-cut evidence dealing with the ability of operant techniques to alter such covert features of reading as comprehension or the formation of inferences.

2. Earlier, it was indicated that under an operant arrangement, reading skills would be acquired on a hierarchical basis from simple to complex behaviors. Further, at each level in the instructional sequence, it is likely that the learner will experience many instances in which his reading efforts are consistently reinforced. An important question which may be raised is what happens to reading behavior once the instructional program is formally terminated and reinforcement contingencies are no longer available. One possibility is that reading behavior established under an operant arrangement will deteriorate. This conclusion is partially based on the premise that external reinforcers are essentially "bribes" or props for reading behavior which, when withdrawn, leave the learner with no alternative motivational basis for reading activities. In contrast, the hypothesis argued for in this report is that any behavior which is strongly and consistently reinforced over the course of many instructional sessions will acquire reinforcing values in and of itself; i.e., become intrinsically rewarding. It is thus presumed that at least some of the underpinning of a self-reinforcement system may be initiated through an extrinsic reinforcement system used during early reading instruction. In testing these contrasting hypotheses, attention would be directed to indices of reading activity during and subsequent to formal operant instruction.

3. A central feature of an operant instructional system involves the utilization of salient reinforcers. But what may be an adequate reinforcer to one individual may be inadequate for another. An important problem, therefore, is the basis for selecting one class of potential reinforcers over another as the means of strengthening and motivating reading behavior. Premack (1965) has suggested an intriguing approach to cope with this issue; namely, that an array of objects and activities vary in the degree of subjective attractiveness to an individual. Further, a more preferred commodity or activity may be used as reinforcers for less preferred activities. Given this proposition, it would be necessary first to assess the attractiveness of reading relative to other activities. Once the relative preference ranking of reading is determined, it should be possible to select an optimum reinforcer for reading behavior. As yet, there has been no formal evaluation of Premack's hypothesis within an applied learning situation. Research within this area would further contribute to formulating explicit rules for constructing an instructional system based upon operant strategies.

4. A somewhat related issue involves the possibility that responsiveness to reinforcement contingencies also reflects basic cognitive and personality characteristics of the learner. Some current research by Katz (1967) and Barron (1970) points up the possibility of such a relationship. Barron found, for instance, that socially disadvantaged

adolescents who score high on the Crowne-Marlow scale measuring need for social approval performed better on simple laboratory learning tasks under conditions of verbal reinforcement (approval versus disapproval) than under conditions of tangible reinforcement. Considering the emphasis placed in this paper on the central role of reinforcement, research is needed to determine the extent to which learner characteristics must be incorporated as a component in the design of operant instructional systems.

5. It is clear that the instructional strategies which have been outlined are likely to have a strong interpersonal component. This is because the effective utilization of reinforcement contingencies probably requires a close pupil-teacher relationship. Research by Katz, Henchy, and Allen (1968) and Stevenson (1965) have indicated that experimenter-examiner characteristics, such as sex, social-class background, and race, may exercise a profound influence on performance outcomes of subjects. For example, Katz (1967) noted that the performance on a verbal-learning task of black elementary pupils was significantly better under testing conditions administered by a black than by a white examiner. These results are suggestive of an additional research area; namely, investigating the extent to which instructor characteristics may influence performance outcomes under an operant instructional framework.

6. There is evidence to indicate the usefulness of operant strategies in teaching reading skills, particularly involving situations in which there is a one-to-one relation between pupil and teacher. However, there is little or no information regarding how operant procedures may be adopted to typical classrooms involving many students. In particular, how may the operant requirement of a precise relationship between response and reinforcement be maintained under conditions in which numerous pupils' responses are likely to occur close together in time? Perhaps the answer lies in the development of auto-instructional reading materials which are so structured as to provide not only for prompt reinforcement of reading responses but for provisions that enable a teacher to monitor, in a relatively continuous fashion, the learning efforts of many pupils.

Complimenting this issue, there is the intriguing possibility of extending the resources of a teacher by training para-professionals in the use of operant procedures to teach early reading skills. However, little is known regarding the instructional impact of such sub-professionals on learning outcomes. For example, can disadvantaged adolescents be trained to use operant procedures effectively to tutor younger disadvantaged children? If there is evidence of growth in reading skills in younger children, one might also speculate that such positive learning outcomes would

generalize to the tutor as a result of his systematic instructional involvement with his pupil. These questions represent just a sampling of important research issues in this area.

A POSTSCRIPT

It has been pointed out by Kuhn (1962) in his historical analysis of science that "paradigm clashes" occur intermittently. He refers to intense controversies in which scientific antagonists often characterize their opponents in the most extreme form possible in order to formulate the most potent counterarguments. Concurrently, each emphasizes that the other's criticisms are based on an incomplete understanding of one's theoretical bias.

In the context of psychology, an excellent illustration of such a clash involves the interchange between behavioral versus cognitive theories. Clearly, this paper falls within the behavioral perspective and, accordingly, it represents a sharp contrast to cognitively oriented interpretations of the reading process. The major difference between these interpretations appears to center on the relative emphasis placed on the internal processing of information as contrasted with a focus on an objective description of environmental events which may influence reading behavior.

Further, each position conceptualizes its scientific goals in divergent ways. For some, as in the operant reading model, the goal is the control over the reading process, or the specification of the adequate environmental events which enable the individual to read appropriately. But for others, as in cognitive models, the goal seems to be the formulation of theoretical accounts of internal processing and the specification of structures capable of accounting for reading behavior. In a sense, the emphasis is placed on understanding rather than on control.

As Kuhn (1962) points out, there is nothing in the laws of science which can help us to determine on a logical basis which set of paradigms should be accepted and which rejected. Further, the arguments posed by each group against the other will probably not help to decide which is more fruitful, since each set of arguments is based on premises irrelevant to the opposing framework. Perhaps the most reasonable thing that may be said is that neither approach is entirely satisfactory or convincing. Since the goals of both appear to be at least partially overlapping, it would seem only reasonable to encourage competent researchers to "do their own thing." If Kuhn is correct, intensive work within each perspective will eventually lead to dominance of one approach over the other.

ADDENDUM

Introduction

The following proposal is an effort to illustrate the application of operant concepts to reading research as well as to come to grips with some research issues raised in the main section of this report. Briefly, the proposal involves a comparison of the effects of different classes of reinforcers on the acquisition and maintenance of reading behavior. The proposal is presented in broad outline. To implement this design would require careful detailing of its major components.

It is proposed that money function as one kind of reinforcer in this investigation. Skinner (1953) has stated that money acts as a transituational reinforcer because of its repeated pairing with primary (physiological) rewards. Skinner further indicates that because deprivation states will usually exist for which money is appropriate, monetary incentives as a generalized reinforcer should be capable of exerting strong shaping effects on varied classes of behavior. Unfortunately, valid evidence of the behavioral effectiveness of monetary incentives is minimal. Within the context of reading instruction, Smith (1969) reported on what appears to be the only application of money incentives in reading instruction. In this research, small monetary rewards (1 percent per 10 correct responses) were shown to influence the reading skills of retarded readers in comparison to a control group which received no reinforcing consequences. However, in this research, there was no experimental manipulation of a basic property of money--i.e., its value. A plausible assumption is that with an objective change in monetary value (e.g., from one cent to five cents) there is a corresponding change in the reinforcement potential of money. Accordingly, it might be expected that a change in the value of a monetary reinforcement during instruction should exert some effect on reading performance in comparison to a base line involving reinforcement under a different incentive arrangement. There may, of course, be limits beyond which a change in the value of money might not influence level of reading performance.

Another major focus of the proposed research involves the long-term impact of operant procedures on reading. It has been repeatedly demonstrated within the context of laboratory research that the withdrawal of reinforcement leads to a gradual weakening of a previously reinforced response; i.e., extinction. Interpolating this finding to reading instruction suggests the following issue. Will reading skills acquired under operant procedures weaken when reinforcement is withdrawn, as would be the case once formal instruction is terminated. Consistent with previous observations about the extinction process, the answer would appear to be yes. A different

expectation, suggested in an earlier section of this report, is that reading behavior can be maintained after termination of a program of extrinsic reinforcement. This expectation assumes that a system of intrinsic or self-reinforcement is established or strengthened as a result of the frequent reinforcement of reading efforts during operant instruction. Such a self-rewarding system is assumed capable of maintaining reading skills subsequent to the withdrawal of external reinforcement. Accordingly, it might be anticipated that any increments in reading performance associated with instruction would not be dissipated after the termination of the program. These contrasting propositions would be evaluated within the proposed research.

Experimental manipulations. Table 1 lists the various experimental conditions. The first two conditions focus on monetary reinforcement. In condition one, subjects are given 5 cents for each ten correct responses up to the midpoint of instruction. After that, the subjects are given 20 cents for each ten correct responses. Condition two reverses this pattern; that is, the value of the incentive decreases at the midpoint of the instructional program. Condition three, which provides for a fixed monetary reward throughout the course of the experiment, represents a control comparison for the variable-incentive conditions. Overall, the first three conditions evaluate the effects of magnitude of monetary reinforcement as well as alterations in its effect on reading behavior.

In condition four, monetary rewards are to be replaced with verbal evaluative reinforcement from the teacher (e.g., "good," "that's right," "a good job") contingent upon the pupil satisfactorily completing successive segments of reading activities during an instructional period. In condition five, reinforcement is in the form of prompt feedback to the pupil regarding how well he has performed during each instructional period. The form of this feedback might be a graph, prepared jointly by the teacher and pupil, which charts his performance level for each instructional period. In condition six, a pupil is given access to some preferred leisure activity or game which is contingent upon satisfactory completion of a work contract (representing a defined segment of instruction). Finally, in condition seven, no reinforcing consequences are provided during instruction. This condition provides a baseline or comparison for the other reinforcement groups.

Experimental procedures. Ideally, the study should utilize instructional materials which have a programmed format. Such programmed lessons should have the following features: (a) the materials require frequent responding on the part of the student; (b) the instructional materials should be self-contained, permitting self-pacing on the part of the student. The former feature is important from the

TABLE 1

SUMMARY OF EXPERIMENTAL CONDITIONS

Condition	Manipulation	Example
One	Variable incentive Value: increasing	5 cents per each 10 correct responses, increasing to 20 cents per each 10 correct responses (change made at the midpoint of instruction)
Two	Variable incentive Value: decreasing	20 cents per each 10 correct responses, decreasing to 5 cents per each 10 correct responses (change made at the midpoint of instruction)
Three	Fixed incentive Value	10 cents per each 10 correct responses throughout the course of the experiment
Four	Verbal evaluation	Evaluative comments from the teacher (e.g., That's good) contingent upon completion of fixed segments of the instructional materials
Five	Feedback or knowledge of results regarding a pupil's progress during an instructional period	A graph is prepared of a student's daily progress
Six	Activity or game contingent upon completion of a work contract	Free play contingent upon completing a fixed amount of instructional materials
Seven	No reinforcing consequences	------------

standpoint of providing discrete, easily countable responses which may then be related to specific reinforcing consequences. The teacher's role is conceived of as a manager of the learning environment, maintaining task-relevant behaviors, providing reading materials, monitoring reading efforts, cueing pupil responses wherever necessary, and providing particular reinforcing consequences corresponding to the experimental conditions described above.

Subjects

It has been emphasized that operant procedures may have their greatest applicability in training early reading skills. Consistent with this position, the subject pool for the proposed study should consist of elementary-school children within a defined age range who are experiencing difficulty in acquiring reading skills appropriate for their age level. As a means of minimizing confounding factors, variables such as social class and intelligence need to be controlled by identifying subjects falling within defined categories and assigning them on a random basis among all of the experimental conditions. Since repeated measures would be obtained over several instructional sessions, it seems reasonable that relatively few subjects would be required for any one condition.

Analysis

The major analysis would focus on comparisons between reinforcement groups with respect to indices of reading performance (e.g., number of correct responses) over the several sessions of instruction. Beyond the intergroup comparisons, attention needs to be given to long-term indices of reading subsequent to formal operant instruction. A number of standardized reading tests might be used over an extended period of time to determine the permanency of any improvement in reading skills attained during instruction.

Implications

The proposed research will provide a basis for comparing a presumed strong reinforcer with other classes of extrinsic reinforcers. Accordingly, the research should provide important cues regarding the kinds of reinforcers that may influence reading performance.

REFERENCES

Barron, R. The SRS model as a predictor of Negro responsiveness to reinforcement. Journal of Social Issues, 1970, 26, 61-81.

Frase, L. T. Boundary conditions for mathemogenic behaviors. Review of Educational Research, 1970, 40, 337-347.

Gagné, R. M. The conditions of learning. (2nd ed.) New York: Holt, Rinehart, & Winston, 1970.

Gibson, E. J., Pick, A., Osser, H., & Hammond, M. The role of grapheme-phoneme correspondence in the perception of words. American Journal of Psychology, 1962, 75, 554-570.

Hall, R. V., Lund, D., & Jackson, D. Effects of teacher attention on study behavior. Journal of Applied Behavior Analysis, 1968, 1, 1-12.

Hershberger, W. A., & Terry, D. F. Delay of self testing in three types of program texts. Journal of Educational Psychology, 1965, 56, 22-30.

Katz, I. The socialization of academic motivation in minority group children. In D. Levin (Ed.), Nebraska Symposium on motivation. Lincoln: University of Nebraska, 1967.

Katz, I., Henchy, T., & Allen, H. Effect of race of tester, approval-disapproval, and need on learning in Negro boys. Journal of Personality and Social Psychology, 1968, 8, 38-42.

Krasner, L. Studies of the conditioning of verbal behavior. Psychological Bulletin, 1958, 55, 148-170.

Kuhn, T. S. The structure of scientific revolutions. Chicago: University of Chicago Press, 1962.

O'Leary, D. A. A token reinforcement system in the public schools. Paper presented at the convention of the American Psychological Association, San Francisco, 1968.

Premack, D. Toward empirical behavior laws. I. Positive reinforcement. Psychological Review, 1959, 66, 219-233.

Premack, D. Reinforcement theory. In M. R. Jones (Ed.), Nebraska Symposium on motivation. Lincoln: University of Nebraska Press, 1965.

Raygor, A. L., Wark, D. M., & Warren, A. D. Operant conditioning of reading rate: The effect of a secondary reinforcer. Journal of Reading, 1966, 9, 147-156.

Rosen, B. C. The achievement syndrome. A psychocultural dimension of social stratification. American Sociological Review, 1956, 21, 205-211.

Rothkopf, E. Z. Learning from written instructional materials: An exploration of the control of inspection behavior by test-like events. American Journal of Educational Research, 1966, 3, 241-249.

Rothkopf, E. Z. The concept of mathemagenic activities. Review of Educational Research, 1970, 40, 325-336.

Skinner, B. F. The behavior of organisms. New York: Appleton-Century-Crofts, 1938.

Skinner, B. F. Science and human behavior. New York: Macmillan, 1953.

Skinner, B. F. Verbal behavior. New York: Appleton-Century-Crofts, 1957.

Smith, D. E. P. Increasing task behavior difficulty in a language-arts program by providing reinforcement. Journal of Experimental Child Psychology, 1969, 8, 45-62.

Staats, A. W. Learning, language, and cognition. New York: Holt, Rinehart, & Winston, 1968.

Staats, A. W., & Butterfield, W. H. Treatment of nonreading in a culturally deprived juvenile delinquent: An application of reinforcement principles. Child Development, 1965, 4, 925-942.

Staats, A. W., & Staats, C. K. A comparison of the development of speech and reading behavior with implications for research. Child Development, 1962, 33, 831-846.

Staats, A. W., Staats, C. K., Schultz, R., & Wolf, M. M. The conditioning of textual responses using extrinsic reinforcers. Journal of Experimental Analysis of Behavior, 1962, 5, 33-40.

Staats, A. W., Finley, J. R., Minke, K. A., & Wolf, M. M. Reinforcement variables in the control of unit reading responses. Journal of Experimental Analysis of Behavior, 1964, 7, 139-149. (a)

Staats, A. W., Minke, K. A., Finley, J. R., Wolf, M. M., & Brooks, L. O. A reinforcer system and experimental procedure for the laboratory study of reading acquisition. Child Development, 1964, 35, 209-231. (b)

Stevenson, H. H. Social reinforcement of children's behavior. In L. P. Lipsett & C. C. Spiker (Eds.), Advances in child development and behavior. Vol. 2. New York: Academic Press, 1965.

Terrell, G., Durkin, K., & Wiesley, M. Social class and the nature of the incentive in discrimination learning. Journal of Abnormal and Social Psychology, 1959, 59, 270-272.

Walker, H. M., & Buckley, N. K. The use of positive reinforcement in conditioning attending behavior. Journal of Applied Behavioral Analysis, 1968, 1, 245-250.

Zigler, E., & Kanzer, P. The effectiveness of two classes of verbal reinforcers on the performance of middle-class and lower-class children. Journal of Personality, 1962, 30, 157-165.

THE INFLUENCE OF WRITING-SYSTEM CHARACTERISTICS ON LEARNING TO READ

William B. Gillooly

Rutgers University

A DEFINITION OF WRITING

Characteristics of our traditional English writing system, such as irregular grapheme-phoneme correspondences, have long been blamed for some of the difficulties encountered by children when learning to read. This paper seeks (a) to analyze this writing system so as to develop some hypotheses about the effects its characteristics have on reading performance, and (b) to examine the evidence that bears on the hypotheses. We will begin with a definition.

Writing has been defined as "a system of intercommunication by means of conventional visible marks [Gelb, 1963, p. 253]." For our purposes here, however, we will consider writing to consist of <u>the assignment (or mapping) of symbols to sounds according to rules in order to represent spoken language</u>. It should be noted that there are three elements in our definition: symbols, sounds, and rules.

The result of the mapping operation referred to in our definition is the production of a corpus of written language which is divisible into various units of analysis. In some cases, these units are the familiar units of spoken language; sentences, phrases, and morphemes. This is not always the case, however. For example, the concept of a word (or, at least, word division) seems peculiar to writing (i.e., spelling conventions) and, consequently, "cannot" is written as one word and "will not" as two (Gleason, 1961). Perhaps this is why children do not identify words in a corpus of written language prior to receiving formal reading instruction (Brush & Tither referred to in Gibson, 1970).

It is widely acknowledged that writing systems do not provide a complete transcription of speech, although Gattegno (1970) is one of those who does not agree. Although most modern writing systems represent the segmental phonemes of language, some better than others (Bloomfield, 1942), none provides an adequate representation of the suprasegmental phonemes of pitch, stress, and juncture (Carroll, 1964). Some aid is

provided in the form of punctuation, of course, but this is not completely adequate (Whitehall, 1956). Consequently, Chomsky (1970) has no difficulty presenting a phrase "American history teacher" which is ambiguous in print (does it refer to an American teacher of history or a teacher of American history?). In spoken language, of course, the issue is resolved by stress and juncture (and context would help in both spoken and written language).

Our traditional writing system has been the object of widespread controversy. As long ago as 1551, John Hart (1551) suggested that changes were necessary because of "irregularities." In order to specify the nature of these alleged irregularities, we must analyze our traditional English orthography.

AN ANALYSIS OF TRADITIONAL ENGLISH ORTHOGRAPHY

If our writing system is irregular, as widely asserted, we should find the causes of such irregularity in its component parts. We will take up in the following order each part of our writing system: symbols, sound base, and rules of correspondence.

The Symbol System

One of the most persistent criticisms of our writing system by those who would reform it is that it suffers from a symbol shortage. The fact of such a shortage is often based on the claim that while there are 40 or so phonemes in English, although Miller (1951) believes 30 may be a more realistic figure, there are only 26 letters in the Roman alphabet that we use to represent them. Three of these, <c>, <q>, and <x>, are believed to be redundant (Downing, 1967). Those leveling the charge of a symbol shortage, in addition to John Hart (1551), include George Bernard Shaw (1946) and Gattegno (1962). This symbol shortage is presumed to preclude the use of a particular symbol to represent only one sound, thereby producing irregularity. A quotation from King and Pitman (1960) demonstrates such reasoning:

> . . . we have too few <u>characters</u> to match the <u>sounds</u> of English speech. We write "not her" and the values of "t" and "h" appear to the child clearly in their normal use. We then write "mother," changing only the en to em, and it is at once apparent that there is no normal "t" sound nor normal "h" sound in "mother," but another English sound altogether. . . .

The remedy suggested by those who hold this belief is augmentation. Shaw (1946) thought we need "not less than 42

letters"; Pitman's Initial Teaching Alphabet (i.t.a.) contains 44; and Leigh's Pronouncing Orthography (Gillooly, 1968) contains 70 symbols. However persuasive such arguments may at first appear, recent evidence indicates that our writing system is not so symbol-poor as some have thought.

In the case of phonetic writing systems, individual graphemes (letters) are the functional units that are mapped on to sound. In other systems, such as English, the graphemic units are more complex, involving not only single letters but also compounds (letter sequences) formed of more than one letter. Examples are the digraphs <th>, <ch>, <ck>, <oo>, etc., that function in a way different from the simple, combined effects of their constituent letters. In other words, the letters <th> when functioning as a graphemic unit do not stand for a blend of the sounds represented by <t> and <h> when each is acting as a separate graphemic unit. This is, of course, the point made by King and Pitman (1960) cited above. However, the reader of English avoids the difficulty alluded to in that quotation by the application of rules which govern the operation of the compound graphemic units. In the example cited, the child learns that letters do not serve as functional units across word boundaries (the space between <not> and <her>) nor across morphological boundaries within words <mis-hap>. Other aspects of their operation (such as vocalization) are similarly rule-governed.

As a consequence of these graphemic patterns, English orthography employs far more than 26 <u>functional units</u>. One group of research workers has identified 69 letter groupings which operate as graphemic units in written English (Berdiansky, Cronnel, & Koehler, 1969). Venezky's (1967) analysis has disclosed only 65, however.

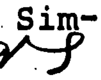
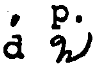
Another feature of written English is the use of marker units (Venezky, 1967). These are letters or letter sequences which, although sometimes being unsounded themselves, affect the sound of other letters in their environment (as the <e> in <mate> affects the vowel sound of <a> and as the second <t> in <thought> affects the sound of the digraph <th>).

Hence, our English writing system is not so symbol poor as some have believed. Rather, its symbol system--at least at the level at which the system is related to sound--is more complex than most. That it will take the child more time to learn the rules governing the functional units of English orthography than of some other orthographies seems obvious. Later we must take up the question of whether this additional investment yields dividends, but first we will consider the sound base of our writing system.

The Sound Base of English Orthography

In written languages, symbols may stand either for meaning or experience directly (as the snake-like form on the yellow, triangular traffic sign stands for curves in the road) or they may stand for the sounds of spoken language which, in turn, are related to meaning. Those of the latter class, the phonographic writing systems, have been the more important to the development of civilization.

There are four classes of phonographic writing systems, according to the units of sound which are represented by their symbols: phraseographic, logographic, syllabic, and the familiar alphabetic. In all of the phonographic writing systems it is appropriate to refer to symbol-sound relationships, but each class differs from the others in terms of the chunk of sound represented by each symbol.

Examples of phraseographic writing, wherein a symbol represents a phrase, may be found in the Gregg Shorthand Simplified System (Leslie & Zoubek, 1950, p. 348). There,  represents "I should like to have" and  stands for "if you want." This is one of the features of stenographic systems that permit their users to encode the sound stream of language with great speed.

In logographic writing, since each symbol must stand for a word, there is need for a large number of symbols. Our numeral writing system is logographic (with <3+3=6> representing the statement, "three plus three equals six"). A description of six classes of logographs may be found in Gelb (1963, pp. 99ff).

Many of the ancient writing systems (such as Cuneiform) employed symbols to represent the syllables of their spoken language. In addition, the Japanese writing system of today is, in part, a syllabary. When one uses three letters of our Roman alphabet to indicate "I owe you" by <IOU>, he is using a syllabic writing system.

In alphabetic writing, the symbols stand for the most elementary units of sound, the phonemes. Therefore, while it is appropriate to speak of symbol-sound relationships in all of the phonographic writing systems, grapheme-phoneme relationships may exist only in the alphabetic writing systems. Although our English writing system is phonemically based, it is not a phonemic (or phonetic) writing system in the sense that each symbol stands in one-to-one correspondence with a single sound element.

Does the sound base of a writing system make any difference in terms of the ease with which literacy is acquired? Gelb (1963, p. 203) reports a number of papers in which the

point is emphasized that literacy is acquired with extraordinary ease in syllabic writing systems. In addition, data are available from Japan where children are introduced to literacy via a syllabary. These data indicate that there are relatively few cases of reading disability in that country (Makita, 1968).

Although it is convenient to do so for reasons of presentation, in fact, no writing system belongs solely to one or another category. Each is likely to contain elements from a number of classes. This is due in part to the principle of uni-directional development (Gelb, 1963) which refers to the fact that, historically speaking, writing systems have developed in a single direction--using symbols to represent ever-smaller segments of the sound stream of spoken language. Hence, all alphabetic writing systems have developed out of syllabaries which, in turn, developed out of logographic systems and, may have retained, to varying degrees, the characteristics of the earlier forms. Uni-directional development seems to have led, in general, to writing systems employing fewer and fewer distinct symbols. Consequently, emphasis in literacy instruction has shifted from learning relatively large numbers of symbol-referent correspondences to a reliance on rules for arranging the smaller set of symbols into unique sequences. This brings us to the next characteristic of writing systems--the rules of correspondence.

Rules of Correspondence

The rules of correspondence of a writing system determine how the symbols are mapped on to the sounds constituting the base of the writing system, thereby establishing not only the sound-symbol correspondences but, more germane to our concern, the symbol-sound correspondences as well.

That words are not spelled simply in English (that is, with one symbol representing one and only one sound) is well known to every literate person of the language. Examples of complexity in written English abound. There are at least twenty different ways of spelling the sound "eye" (Pitman, 1970).

Because of this complexity, the idea is widespread that there is something wrong with our writing system. One frequently mentioned hypothesis, refuted by the earlier discussion of symbol systems, is that there are not enough symbols in the Roman alphabet to represent unambiguously the sounds of English. While superficially true, it may be recalled that our writing system circumvents the possibility of a symbol shortage by the use of letter sequences (digraphs, marker units, etc.), which function as graphemic units.

Another hypothesis is that for a variety of reasons (including the meddling with the spelling of English words so as to bring them to reflect their etymology), the rules of correspondence, never very adequate, have developed an increasing number of problems (Fries, 1963). Apparently, in exasperation, one wit named Fish even suggested that his name be spelled <Ghotiugh> in English. He derived the sounds as follows:

> <gh> is the /f/ sound in "tough";
> <o> is /i/ sound in "women";
> <ti> is the /sh/ sound in "station"; and
> <ugh> is silent as in "dough" [Gelb, 1963, p. 225].

In discussing whether the rules of correspondence of a writing system are simple or complex, we must determine not only to what it is that the symbols correspond (that is, determine the base of the writing system, as we have done above), but also the nature of the correspondence. In English, specifying the latter characteristic has been difficult.

Because of the obvious relationship that exists between symbol and sound in any phonographic writing system, many have assumed that the relationship should be a direct one; that is, not mediated by other levels of representation. When traditional English orthography is compared with the criterion supplied by such a notion, our writing system certainly is complex. As we have noted already, individual symbols do not map directly onto the sounds of English in any consistent one-to-one fashion. Hence, at the simplest level, the grapheme-phoneme correspondences of our writing system seem irregular.

However, scholars have begun to seek an underlying regularity in traditional English orthography beyond the level of grapheme-phoneme correspondences, a regularity that is mediated, or indirect. And, their search has been rewarding. As a result of such activity, it can be stated that because our English writing system is deficient as a phonetic (or phonemic) transcription of the spoken language, it does not follow that it is a poor, or an irregular one (C. Chomsky, 1970; Reed, 1966; Venezky, 1967, 1969). We will discuss papers by Venezky (1967) and N. Chomsky (1970) that are pertinent to this issue.

After deriving the functional units of English orthography (groupings of individual graphemes), Venezky (1967) mapped these units first onto a morphophonemic level and then onto speech. N. Chomsky (1970) has related symbols to a level of "lexical representation" of language and then to speech. Both have found far more regularity in our writing system than

is commonly supposed to exist. These ideas, therefore, merit closer scrutiny.

Using a computer, Venezky (1967) derived and tabulated the spelling-to-sound correspondences of the 20,000 most commonly occurring English words. One of his findings, that there are more than 26 functional spelling units in traditional English orthography, has already been mentioned (q.v., symbol systems, above). He then examined his data-seeking rules, which relate the derived spelling patterns (i.e., the functional units) to the total structure of our language. As a result of this analysis, he was led to conclude that:

> . . . English spelling is not simply a defective phonemic system for transcribing speech, but instead a more complex and more regular set of patterns in which both phonemic and morphemic elements share leading roles [p. 267].

In other words, Venezky found that in order to relate graphemic patterns to sound patterns in regular fashion, it was necessary to map via an intermediate morphophonemic level. Consequently, although the digraphs <sh> and <ph> seem at first glance to have irregular soundings in the words <mishap> and <shepherd>, they do not when one considers that they occur at morphological boundaries (we have already noted that functional units do not transcend such boundaries). Additional sound shifts that give an initial appearance of irregularity (such as the change in the sound of <t> in <salivate, salivation>) are also seen to be rule-governed if other elements of the words are taken into consideration: the marker unit <e> in the first case and the suffix <ion> in the second.

Analysis of the functioning of the morphophonemic level suggests that there are two classes of correspondence rules operating during reading, as diagrammed in Figure 1. One class of rules (those involved in mapping graphemes onto morphophonemic forms) is unique to reading whereas the other (which map from the morphophonemic level to sound) is possessed by all speakers of a language.

<mishap>	—A→	mis hap	—B→	"mis'hap"
graphemes (symbols)		morphophonemic level		phonemes (sounds)

Fig. 1. Two classes of correspondence rules, only one of which, A, is involved in reading.

Proceeding in a different way, N. Chomsky (1970) has, nevertheless, come to some conclusions remarkably similar to those of Venezky. Based on an analysis of the relationship

between English phonology and orthography, he has postulated an abstract form of words which, although it underlies their phonetic form, is not identical to it and, hence, is not restricted to sound. Further, the form is possessed alike by all speakers of a language. He calls this the "lexical representation" or the "lexical spelling" of a word. Perhaps an example will help make clear the nature of lexical form.

As suffixes are added to the word "nation" to form the variants ("national," "nationality," etc.), there is a vowel shift (a common one in English) which is not reflected by our traditional orthography. A phonetic transcription such as that provided by, say, the Initial Teaching Alphabet would take such a vowel shift into account, of course, and represent the different sounds with a different symbol, thereby preserving phonetic reality. Because traditional orthography does not do this--it spells the different vowels similarly--it must answer to the charge of being irregular. It is the invariant root spelling of such a word in the traditional orthography that Chomsky refers to as the "lexical spelling." He points out that by maintaining similar root spellings across variant forms of a word without regard to vowel shifts, our traditional orthography represents similarities of meaning which are real in the language. For example, "nation" and "nationality" have common meanings but not common uses in a sentence and our orthography preserves the similarity of meaning and signals the different usage (and vowel sound) by the addition of a suffix. Because it makes provision for preserving the meaning-relevant features of words, Chomsky concludes that our language may be close to optimal in the way its spelling relates to the structure of the spoken language. This notion extends Gleason's (1961) idea that our English writing system is only partially phonologic.

What are the implications for reading of such a view of our orthography? According to such an analysis, the child who reads <nationality> correctly responds first to the root (the lexical unit), modifying its pronunciation in accordance with phonological principles brought to the reading task by any speaker of English. These principles, in turn, are triggered by syntactical rules and the addition of graphemes (a suffix) to the lexical form.

What purpose is served by our writing system's preserving the meaning-relevant forms of language? It has been proposed (C. Chomsky, 1970; Gibson, 1965) that a child begins by decoding small graphemic units, perhaps individual graphemes, and then gradually moves on to ever-larger graphemic units. This process is probably facilitated by the fact that our writing system omits redundant phonetic information (recall that a speaker brings this information to the reading situation with him) and thereby permits more rapid transition to the semantically significant units of language

(N. Chomsky, 1970). In other words, by "chunking" information in meaning-relevant but not sound-relevant ways, our writing system encourages the reading of large graphemic units. The result would seem to be faster reading for those experienced readers who are processing lexical units.

The findings of Venezky (1967) also suggest why children come, in time, to read ever-larger chunks of written language. Because the English symbol system is organized in terms of graphemic units (i.e., sequences of graphemes), not individual graphemes, children are rewarded for seeking correspondences beyond the individual letter; that is, between clusters of letters and sounds. There are a number of implications here. First, because the child learning to read English is faced with a more difficult task (he must learn to respond to letter groupings and the rules by which such groupings operate) than if our writing system were strictly phonetic, his initial progress should be slow. However, as he develops skill and begins to process ever-larger graphemic units, he should surpass children who are not using a writing system with the features of English orthography.

Second, because our writing system represents regularities which exist at deeper levels in our language and is not tied directly to phonetics, it avoids problems which, because of dialect variation in American English, could plague a phonetic writing system (Ives & Ives, 1969). Hence, our writing system has what could be called "dialectal adaptability" and should, therefore, serve a wide range of readers. Only to the extent that dialects differ at the syntactic and lexical levels should they be a source of variance.

English orthography has some disadvantages, too. For, even after his reading skill develops, the English reader, in processing lexical units, will miss a suffix here and there. When this happens, he must do some guessing (Goodman, 1965).

It must be kept in mind that we have been discussing the symbol-to-sound (grapheme-phoneme) correspondences of English because they constitute the class of correspondences pertinent to reading. If, however, one is interested in writing or spelling, or both, it is the sound-to-symbol (phoneme-grapheme) correspondences that are germane. Although it is not within the scope of this paper to discuss these, it should be noted that symbol-sound and sound-symbol correspondences are not necessarily reversible in a writing system and certainly not in English (Cronnell, 1971). One large study of the phoneme-grapheme correspondences in English has been reported by Hanna, Hanna, Hodges, and Rudorf (1966) and their effect on the distribution of spelling errors within words has been reported by Jass and Gillooly (1971).

Conclusion

Based on the preceding analysis of English writing, it may be concluded that ours is not an irregular; that is, unlawful system. Rather, its regularity is of a more complex, indirect sort than of phonetic (or phonemic) writing systems. Basically, the symbol-sound correspondences in our traditional orthography exist between graphemic units (letter sequences) through some intermediary (morphophonemic) level, to sound. As a consequence, our writing represents elements of meaning as well as elements of sound. While this complexity may result in initial difficulty and delay in acquiring literacy, it may provide advantages overall in terms of reading speed and adaptability to a wide range of dialect in beginning readers. All of these conclusions are hypotheses that require empirical investigation. In Part II of this paper we will review the data which bear on some of these questions.

THE BEHAVIORAL EFFECTS OF WRITING-SYSTEM CHARACTERISTICS IN LEARNING TO READ

Earlier in this paper, writing was defined as "the assignment (or mapping) of symbols to sounds according to rules in order to represent spoken language," and an analysis of our English writing system in terms of its component parts (symbols, sound base, and rules of correspondence) was undertaken. As a result of that analysis, several hypotheses were developed. In this part of the paper, the data bearing on the several hypotheses will be considered.

Is it more difficult to learn to read traditional English orthography (t.o.) than a more phonetic (or phonemic) writing system? There are two kinds of data that we will consider in answering this question: (a) those resulting from the use of transitional writing systems, and (b) cross-national data.

Data from the Use of Transitional Writing Systems

Transitional writing systems (TWS) are those phonetic or phonemic writing systems that have been developed for the purpose of introducing children to reading and writing and are, therefore, intended only for temporary use. The list of TWS is an extensive one, including Isaac Pitman's Phonotypy, Edwin Leigh's Pronouncing Orthography, and Edward Fry's Diacritical Marking System (Fry, 1964). The best-known TWS today is, perhaps, James Pitman's Initial Teaching Alphabet (i.t.a.). A comprehensive history of the nineteenth-century use of transitional writing systems has been compiled by Bothe (1967).

Because it has been researched so extensively, we will turn first to experimental data arising from the use of i.t.a. to help answer the question of the difficulties which result from the use of a writing system such as traditional English orthography. Before doing so, however, we should analyze the Initial Teaching Alphabet.

An Analysis of the Initial Teaching Alphabet

The i.t.a. symbol system. The i.t.a. has 44 graphemes (Appendix I), 24 of which are identical to those in the Roman alphabet (minus <q> and <x>). In addition, there are 20 additional symbols (hence, its original name: Augmented Roman Alphabet), 14 of which are ligatured characters (for example, <æ>, <œ>, etc.). Hence, complex graphemic units are designated by ligature. This is one provision of the symbol system intended to help readers avoid the necessity of regressive eye movements. There are no uppercase letters (i.e., capitals). Sentences begin, therefore, with a larger version of the lowercase character. The rationale given for this design is that it reduces the number of whole-word configurations a child must learn when using a whole-word approach to reading (Downing, 1967, p. 10).

The i.t.a. sound base. The i.t.a. is an alphabetic writing system in the sense that its symbols represent the elemental sounds of English. Although it is not, strictly speaking, a phonetic writing system, it has many of the characteristics of one (MacDonald, 1970). With a writing system so phonetically based as i.t.a., it would be possible to have a number of different spellings for a word--one for each of a variety of dialects. For practical purposes (i.e., the economics of publishing), however, it has been desirable to base i.t.a. on one particular dialect in each country where it is used. In Britain, it is based on ". . . that carefully articulated, sometimes Scottish, speech which is widely understood and accepted when delivered from public platforms, the stage, over the radio, or on the talking film [Downing, 1967]." In the United States, also, i.t.a. has been based on a "standard" dialect.

i.t.a.'s rules of correspondence. There are two reasons why i.t.a. is not so consistent a writing system as it could be: (a) the need, imposed by its transitional nature, to adhere within tolerable limits to traditional orthography (t.o.); and (b) its need, for practical economic reasons, to reflect a "standard" dialect of English (MacDonald, 1970).

An example of the kind of inconsistency brought about by the first reason is as follows: the ligatured <ch> character used in i.t.a.'s spelling of "church" and "which" is not used in a word such as "nature" (i.t.a. spelling, <nætuer>),

although the words do share a common sound. The rationale provided by Pitman for this inconsistency is the need to avoid departing too far from traditional English orthography (the reader should recall that i.t.a. is a transitional writing system and students must, therefore, eventually transfer from it to t.o.). It is a well-known principle of transfer that the higher the degree of stimulus similarity between two situations, the degree of response similarity being high and equal, the greater the positive transfer (Osgood, 1949).

Secondly, because i.t.a. pays particular attention to the rendering of vowels (vowels being the way in which most dialects differ), and because it represents the vowels of a "standard" dialect, the child of other than the standard dialect who is reading it must map the i.t.a. vowel symbols to the sounds of his dialect in a way similar to that necessitated by traditional orthography (q.v., rules of correspondence, above); that is, in indirect fashion.

Despite the fact that i.t.a. is not so consistent as a phonetic writing system, it is, nevertheless, a far more simple orthography than t.o., simple enough, in fact, to provide a useful test of the difficulty children experience in learning to read traditional English orthography.

The Experimental Data

Two well-controlled studies in the United States have reported data comparing children reading i.t.a. with others reading t.o. In one, the comparison is made after about four months of instruction (Hayes & Nemeth, 1966) and in the other, after seven months of instruction (Chasnoff, 1965). In both, the test used was the Stanford Achievement Test, Primary I, Form W (printed in i.t.a. for the experimental groups). A detailed explanation for the procedures used in these studies to control extraneous variables may be found in Gillooly (1966), but the most important uncontrolled factor was the reading material employed in the two experimental conditions.

The results show that although the i.t.a. youngsters were superior to the t.o. after both four and seven months, the superiority was quite specific in terms of the subtests of the Stanford Achievement Test. In both cases, the i.t.a. children scored higher on the Word Reading, Word-Study Skills, and Spelling subtests (with i.t.a. spellings scored as correct for those groups).

Further evidence of the specificity of such writing-system effects is reported by Chasnoff who found significant differences (in terms of median grade scores on the Stanford) favoring the i.t.a. groups only among those of "medium" intelligence, as indicated by the California Short-Form Test of

Mental Maturity. The smallest differences were obtained in the "low" groups where, for example, the i.t.a. and t.o. male subjects earned almost identical scores (1.48 vs. 1.47 for t.o.). Of particular interest is the fact that the Paragraph-Meaning scores and the Vocabulary scores were unaffected by the character of the writing system employed (the latter, perhaps, understandably so).

Historical Data

In addition to these findings, there are some historical data bearing on the use of a more consistent writing system than t.o. (Leigh's Pronouncing Orthography--a 70-symbol writing system augmented by a light-faced type of "silent" letters) in Boston during the nineteenth century (Gillooly, 1968). These data, with the effects of materials controlled (that is, with the t.o. materials transliterated to Pronouncing Orthography), show that at the end of the first grade the youngsters who used reading books printed in the simplified orthography were at a point normally reached at the end of the second year (from the Programme of Studies, Boston Public Schools). This progress led to the following statement in the Boston School Committee Report of 1871:

> It is a moderate statement that every pupil instructed under this new method saves a year or more of time in preparing for the Grammar school. Is it not much to add a year to the practical duration of human life? [pp. 7-8].

With a sufficiently simple orthography, it is possible for a child to read materials beyond his level of comprehension. On the average, i.t.a. children exceed their t.o. counterparts in word recognition, but do not exceed them in comprehension. Whether this was happening in Boston cannot be known.

Both of the writing systems we have discussed (i.t.a. and Pronouncing Orthography) are of the transitional variety (that is, used only to introduce students to literacy) and, consequently, the experimental groups were transferred to traditional English orthography after a year's time. In order to answer any questions about whether the specific advantages of using a simplified orthography are maintained, we must turn to cross-national data.

Cross-National Data

Before examining the cross-national evidence, it is important to point out that these data are not subject to such close control of extraneous variables as studies in which the

experimenter can assign his subjects to treatment, etc. Consequently, the effects of differences in writing-system characteristics are likely confounded with the effects of several other variables. So caution is in order as we proceed now.

Our need is for studying the effects of a writing system with grapheme-phoneme correspondences of a more simple and more direct variety than is found in English.

Among the most carefully controlled experiments of the cross-national sort which have come to this writer's attention are the German-American comparisons by Preston (1962). These constituted the so-called Philadelphia-Wiesbaden study. And since German was classified by Bloomfield (1942) as having relatively regular phoneme-grapheme correspondences, this study will serve our purposes. The work of Preston is valuable not only because of the degree of care exercised in its design, but also because the data have been interpreted by both Preston (1962) and by Preston's German counterpart, Schultze (1962). Preston has also presented a rejoinder to Schultze (Preston, 1963).

The results of Preston's work and that of others suggest that:

1. German children are clearly superior to American children in word recognition--at least in the first two grades (Preston, 1953; Samuels, 1969).

2. American children are clearly superior to German children in reading speed both at the fourth- and sixth-grade levels (Preston, 1962, 1963).

3. The results with respect to comprehension are much less certain. Because the differences were sufficiently slight and because the German children were more unfamiliar with standard tests than their American counterparts, Preston (1953) has been led to conclude:

> The writer's personal belief is that the differences in silent-reading comprehension (not speed of reading, where the American superiority is unmistakable) between German and American children are unstable and probably reversible [p. 64].

4. The incidence of reading disabilities is roughly equivalent in the two countries (Bond & Tinker, 1957; Preston, 1963; Samuels, 1969).

It is interesting that these findings parallel the results obtained in this country with i.t.a. It should be recalled that children reading in that writing system were also found to be superior in word-recognition skills but not

in reading comprehension to children reading in traditional orthography.

The American and German pupils in both grades 4 and 6 obtained three scores on tests in their own languages: the Frankfurter Reading Test, the Gates Reading Survey, and a speed-of-reading measure. It turned out that, among the German pupils, the percentages of girls categorized as either "retarded" or "severely retarded" was higher than the percentages of boys so categorized in 10 of the 12 possible differences between percentages (Preston, 1962). Of these differences, four (all of which showed girls with the higher percentages) were significant at the .05 level. Among the American pupils, the percentages of boys categorized as either "retarded" or "severely retarded" were higher than the percentages of girls so categorized in all 12 differences between percentages. Of these differences, nine were significant at the .05 level.

Available evidence indicates that, in the United States, girls tend to exhibit less difficulty in learning to read than boys whether i.t.a. or t.o. is used as the medium of instruction (Chasnoff, 1965; Gillooly, 1967). The characteristics of t.o., therefore, cannot be held responsible for the usual superiority of girls in reading.

Correspondences in the Data

The experimental data indicate that whatever advantage is enjoyed by children who are reading a writing system with more simple, direct grapheme-phoneme correspondences is exerted primarily via an increase in word-recognition skills. That this advantage may give a false impression about the extent of the superiority imparted by the simplified orthography is indicated by the fact that comprehension (measured by the Paragraph-Meaning subtest of the Stanford Achievement Test) is unaffected by the additional word-recognition skills. Preston (1953) seemed to be alluding to a similar phenomenon when he wrote:

> After the experience of hearing these German children read aloud, I began to attach some credence to a generally expressed opinion of German teachers that by the end of the Grade 2 almost any child can read orally (without regard to degree of comprehension) almost anything in print.

Apparently, increases in word-recognition skill beyond a certain limit (no doubt determined by cognitive factors) do not improve reading comprehension (taken in its broadest sense); that is, there seems to be a "threshold effect" operating here. There are a couple of implications to consider.

First, although simplified orthographies are easier to learn to read in the way we have discussed, children may be unable to profit from the advantage they offer. Consequently, it is inappropriate to infer the effects writing-system characteristics may have on learning to read without taking pupil characteristics into consideration. Word recognition is a more difficult task in t.o. but not to the extent that children's reading comprehension suffers.

Second, if this analysis is correct, the nineteenth-century educators who reported marked gains among children reading a simplified orthography may have mistaken increases in word-recognition skill for an overall superiority. If so, one may not expect the children to read more and more difficult materials beyond some definite limit. When this limit is reached, of course, they would have to "mark time." In fact, this phenomenon did occur in Boston (Gillooly, 1968) and, although it is likely that it was not the only factor which led to the demise of Pronouncing Orthography, it was probably one of them.

Finally, the clearest cross-national differences that Preston obtained in grades 4 and 6 were in reading speed (approximately 3-1/2 paragraphs on the Gates Survey Test in grade 4 and 2-1/2 paragraphs in grade 6 after ten minutes of reading). It should be recalled that our analysis of traditional English orthography indicated that a difference in favor of our writing system might obtain with children reading lexical units (q.v., supra, Rules of Correspondence).

THE BEHAVIORAL EFFECTS OF WRITING-SYSTEM CHARACTERISTICS ON MATURE READERS

We have discussed the effects that writing-system characteristics have on the early and intermediate stages of learning to read. But what about their effects after reading has been mastered? The data come to use in two forms: eye-movement studies and studies of reading speed.

Eye movements. Relatively minor variations in the patterns of eye movements across widely different writing systems led Gray (1956) to conclude: ". . . the general nature of the reading act is essentially the same among all mature readers [p. 59]." He based this statement on eye-movement records of readers in Thai, French, English, Spanish, Burmese, Hindi, Arabic, Hebrew, Urdu, Chinese, Japanese, Korean, Yoruba, and Navaho (Gray, 1956) and in German (Waterman, 1954).

Reading speed. The same conclusion (that there are no major differences in reading different writing systems) is supported by a study comparing the reading speed of Chinese and American students at Stanford University (Shen, 1927).

Although it was found that the Chinese students read about six words per second vs. five for the Americans, Woodworth (1938, p. 736) has pointed out that when reading rate is calculated on the basis of content the two groups covered about the same amount of thought per unit of time. And, it should be noted, Chinese and English represent extremes on any dimension along which writing systems may be compared.

CONCLUSIONS

The major conclusions which spring from an analysis of the influence of writing system-characteristics on learning to read are as follows:

1. In the early stages of learning to read (i.e., in the first grade), phonetic writing systems have an advantage over traditional English orthography (t.o.) in terms of greater word recognition skills. However, t.o.'s disadvantage is not so extreme as to impair reading comprehension as measured by widely-used current reading tests (such as the Stanford Achievement Test). In other words, then, the more phonetic writing systems provide a surfeit of word-recognition skills. Such a conclusion suggests that comprehension is a negatively accelerated, increasing function of word-recognition skill.

2. At the intermediate levels (grades 4 and 6) children reading traditional English orthography (rather than a writing system with more simple, direct grapheme-phoneme correspondences) seem to have an advantage in terms of reading speed. This is most likely so because characteristics of our traditional English orthography (such as the use of graphemic and lexical units) probably encourage children to read larger "chunks" of printed material (higher-order units) at an earlier age than is so in countries employing a more phonetic writing system.

3. Once reading skill has been acquired (i.e., among mature readers), writing-system characteristics no longer seem to exert any appreciable influence on the act of reading.

4. To the extent that reading disabilities are related to writing-system characteristics in the first place, they seem to be more a function of the base of a writing system (i.e., whether it is a syllabary, etc.) than of the nature of a writing system's rules of correspondence.

5. Our traditional English writing system seems to be a near-optimal one for learning to read and, therefore, no basis has been found for the claim by spelling reformers that our traditional English orthography should be modified.

NEEDED RESEARCH

The essential research problem stemming from the writing-system area is one of understanding how writing-system characteristics influence learning to read--not the reading process itself once the skill has been acquired. The implication of this statement is that reading involves at least a two- but more likely, a multi-staged process. Any model of reading that seeks to be comprehensive should make provision for both stages.

Basic to an understanding of the influence of writing-system characteristics at the different levels of skill is knowledge of the role played by phonology and the phonographic principle. For example, it seems obvious that to the extent a writing system faithfully encodes speech sounds (is phonetic or, perhaps, better, phonographic), word-recognition skills will be enhanced (provided the encoded sounds are familiar to the learner). But it is not so obvious that, as a result of acquiring reading experience, the influence of this feature of a writing system (the phonographic principle) should diminish as it apparently does. Why does it? The question may be divided into a number of problems including: the role played by (a) a child's vs. the writing system's base phonology; (b) articulation; and (c) teaching methods. The influence of all three should be studied during both beginning and advanced reading.

Some Specific Research Questions

1. Does our traditional English orthography possess the dialectal adaptability claimed for i .?

2. Can a reader learn to "comprehend" writing without decoding symbols to sound (i.e., articulating) as indicated by two early studies? If so, what role (if any) may be played by writing-system characteristics and familiarization in such reading?

3. It is known that, when employed with a simplified orthography, the individual-letter approach to teaching enjoys a general superiority. But, do these results generalize to materials using a more complex orthography or is there a disordinal interaction such that no one method is consistently superior for all materials?

REFERENCES

Berdiansky, B., Cronnel, B., & Koehler, J., Jr. Spelling-sound relations and primary form-class descriptions for speech-comprehension vocabularies of 6-9-year-olds. Inglewood, Calif.: Southwest Regional Educational Laboratory, 1969.

Bloomfield, L. Linguistics and reading. Elementary English Review, 1942, 19, 125-130; 183-186.

Bond, G. L., & Tinker, M. A. Reading difficulties: Their diagnosis and correction. New York: Appleton-Century-Crofts, 1957

Bothe, A. E., Jr. Nineteenth-century experiments with transitional reading media. Final Report of Project No. 7-C-023, U.S. Office of Education, 1967.

Brush, L., & Tither, N. Unpublished manuscript referred to in E. J. Gibson. The Ontogeny of reading. American Psychologist, 1970, 25, 136-143.

Carroll, J. B. Language and thought. Englewood Cliffs, N. J.: Prentice-Hall, 1964.

Chasnoff, R. E. Comparison of the initial teaching alphabet with the traditional alphabet in first-grade reading. Report of Cooperative Research Project No. S-210, U.S. Office of Education, 1965.

Chomsky, C. Reading, writing, and phonology. Harvard Educational Review, 1970, 40, 287-309.

Chomsky, N. Phonology and reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970.

Cronnel, B. A. Spelling-to-sound correspondences for reading vs. sound-to-spelling correspondences for writing. Paper presented to the meeting of the American Educational Research Association, New York, February, 1971.

Downing, J. Evaluating the initial teaching alphabet. London: Cassel & Company, 1967.

Fries, C. C. Linguistics and reading. New York: Holt, Rinehart, & Winston, 1963.

Fry, E. B. A diacritical marking system to aid beginning reading instruction. Elementary English, 1964, 41, 526-530.

Gattegno, C. Words in colour: Background and principles. Reading, England: Educational Explorers, 1962.

Gattegno, C. The problem of reading is solved. Harvard Educational Review, 1970, 40, 283-285.

Gelb, I. J. A study of writing. Chicago: University of Chicago Press, 1963.

Gibson, E. J. Learning to read. Science, 1965, 148, 1066-1072.

Gillooly, W. B. The promise of i.t.a. is a delusion. Phi Delta Kappan, 1966, 47, 545-550.

Gillooly, W. B. The use of i.t.a. in special education: A critical review. Journal of Special Education, 1967, 1, 127-134.

Gillooly, W. B. The Boston reading experiment (1866-1879): The evaluation of an early educational innovation which was a forerunner to the initial teaching alphabet. In J. R. Block (Ed.), i/t/a as a language-arts medium. Hempstead, N. Y.: The i.t.a. Foundation, 1968, 47-53.

Gleason, H. A., Jr. An introduction to descriptive linguistics. New York: Holt, Rinehart, & Winston, 1961.

Goodman, K. S. A linguistic study of cues and miscues in reading. Elementary English, 1965, 42, 639-643.

Gray, W. S. The teaching of reading and writing: An international survey. Paris: UNESCO, 1956.

Hanna, P. R., Hanna, J. S., Hodges, R. E., & Rudorf, E. H., Jr. Phoneme-grapheme correspondences as cues to spelling improvement. Washington, D.C.: U.S. Department of Health, Education, and Welfare, Office of Education, 1966.

Hart, J. The opening of the unreasonable writing of our Inglish toung. London: 1551.

Hayes, R. B., & Nemeth, J. S. An attempt to secure additional evidence concerning factors affecting learning to read. Report of Cooperative Research Project No. 2697, U.S. Office of Education, 1966.

Ives, S., & Ives, J. Linguistics and reading. In A. H. Marckwordt (ed.), Linguistics in school programs. Chicago: National Society for the Study of Education, 1969.

Jass, A. F., & Gillooly, W. B. The effect of phoneme-grapheme correspondences on the distribution of spelling errors. Paper presented at the meeting of the American Educational Research Association, New York, February, 1971.

King, H., & Pitman, I. J. Spelling--a handicap to reading? Teachers World, February 26, 1960, as cited by Downing, 1967 (q.v.).

Leslie, L. A., & Zoubek, C. E. Gregg transcription simplified. New York: McGraw-Hill, 1950.

MacDonald, J. W. Review of Warburton and Southgate's i.t.a.: An independent evaluation and Pitman and St. John's Alphabets and reading. Harvard Educational Review, 1970, 40, 317-325.

Makita, K. The rarity of reading disability in Japanese children. American Journal of Orthopsychiatry, 1968, 38, 57-61.

Miller, G. A. Language and communication. New York: McGraw-Hill, 1951.

Osgood, C. E. The similarity paradox in human learning: A resolution. Psychological Review, 1949, 56, 132-143.

Pitman, J. The right to read: Target for the seventies. In Needs of elementary and secondary education for the seventies. Washington, D.C.: U.S. Government Printing Office, 1970.

Preston, R. C. Comparison of word-recognition skill in German and in American children. Elementary School Journal, 1953, 53, 443-446.

Preston, R. C. Reading achievement of German and American children. School and Society, 1962, 90, 350-354.

Preston, R. C. Issues raised by the Wiesbaden-Philadelphia reading study. Comparative Education Review, 1963, 7, 61-65.

Reed, D. W. A theory of language, speech, and writing. In L. Courtney & P. Tyler (Eds.), Linguistics and reading. Newark, Del.: International Reading Association, 1966.

Rules of the School Committee and Regulations of the Public Schools of the City of Boston. Chapter 12, Regulations of the Primary Schools. In Annual report of the school committee of the city of Boston, 1871. Boston: Rockwell & Churchill, 1872. Pp. 49-54.

Samuels, S. J. Cross-national studies in reading: The relationship between the sound-letter correspondence in language and reading achievement. In J. A. Figurel (Ed.), Reading and realism. Newark, Del.: International Reading Association, 1969.

Schultze, W. Studie über das verständige lesenamerikanischer und deutscher kinder. <u>Westermanns Pedagogische Bieträge</u>, 1962, 14, 188-198.

Shaw, G. B. <u>Letter to tit-bits</u>. March 22, 1946. Cited in J. Downing, 1967.

Shen, E. An analysis of eye movements in the reading of Chinese. <u>Journal of Experimental Psychology</u>, 1927, 10, 158-183.

Venezky, R. L. English orthography: Its graphical structure and its relation to sound. <u>Reading Research Quarterly</u>, 1967, 2, 75-105.

Venezky, R. L. Linguistics and spelling. In A. H. Marckwardt (Ed.), <u>Linguistics in school programs</u>. Chicago: National Society for the Study of Education, 1969.

Waterman, J. T. Reading patterns in German and English. <u>The German Quarterly</u>, 1954, 26, 225-227.

Whitehall, H. <u>Structural essentials of English</u>. New York: Harcourt, Brace & World, 1956.

Woodworth, R. S. <u>Experimental psychology</u>. New York: Holt & Company, 1938.

APPENDIX 1

Initial Teaching Alphabet

æ	b	c	d	ee	
face	bed	cat	dog	key	
f	g	h	ie	j	k
feet	leg	hat	fly	jug	key
l	m	n	œ	p	ɹ
letter	man	nest	over	pen	girl
r	s	t	ue	v	w
red	spoon	tree	use	voice	window
y	z	ʒ	wh	ch	
yes	zebra	daisy	when	chair	
th	th	sh	ʒ	ŋ	
three	the	shop	television	ring	
ɑ	au	a	e	i	o
father	ball	cap	egg	milk	box
u	ω	ω	ou	oi	
up	book	spoon	out	oil	

INFORMATION-PROCESSING MODELS FOR READING-SKILL ACQUISITION*

Duncan N. Hansen

Florida State University

INTRODUCTION

Information-processing models represent a promising framework from which to clarify and develop theoretic representations of the reading-learning process. A most promising feature is that information-processing models allow for greater representation of complex behaviors that are typical of reading. For example, the processes of reading comprehension as they relate to memory and personality processes can be incorporated, in principle, with reading decoding skills within most of the component structures of information processing models (Simon, 1967). This representation of complex processes is possible because of the flexibility found within information-processing-model components and because of the important fact that these component processes can be hierarchically structured or convoluted together in order to approximate the desired degree of complexity and comprehensiveness. A second promising feature of information-processing models is that they allow for a more explicit consideration of the purposive aspects of reading. While one aspect of information-processing models grew out of the goal orientation of robotology (Hilgard & Bower, 1966), this paper will highlight the simulation concepts which have been utilized to specify the purposive behaviors. As a last major merit of information-processing (IP) models, the complete model structure with its component subprocesses can be clearly represented via a computer program. This allows for a component and subcomponent analysis as well as explicit alteration in light of empirical tests and the desire to increase the generalizability and predictability of each model.

Given the view that reading has a multivariate nature, extensive model building will be required in order to gain any generalizability across content, students, and situational

*The author wishes to acknowledge the assistance of H. Dewey Kribs and Barbara F. Johnson in the preparation of this paper.

variables; thus, explicit representation of IP models via computer programs provides a framework for theorizing and hypothesis testing.

Three generic types of IP models will be considered within this paper. These have been selected primarily because of their potential for illustrating IP component processes within models that are highly promising for understanding the reading/learning process. First, the General Problem Solver developed by Simon and his colleagues (Ernst & Newell, 1969) will be reviewed in terms of its emphasis on the concepts of purposive behavior processes, hierarchies, means-ends analysis, memory structures, and personality processes. As a second IP approach, interactive natural language models, as exemplified by the work of Weizenbaum (1966), provide a promising representation of the decomposition and semantic processing requirements so necessary for reading-comprehension skills. Lastly, the instructional models developed by Atkinson (Atkinson & Paulson, 1971) contribute to a theoretical context within which optimal learning sequences can be identified for reading.

After the descriptions of these three kinds of IP modeling approaches, the paper will turn to an analysis of component processes commonly found within information-processing models. These component processes will be categorized as follows: (a) information structures that have implications for word and sentence decomposition, (b) process components that have implications for characterizing the flexibility and rate of reading, and (c) systems processes that have implications for the monitoring and error-correction processes found within reading. The paper will then provide a brief review of recent empirical research findings and conclude with a consideration of future developments likely to occur during the 1970's.

PROTOTYPE IP MODELS FOR READING

General Problem Solver

The General Problem Solver (GPS) represents one of the first attempts to describe human behavior in information-processing terms. The creators of this computer-based model, J. C. Shaw, H. A. Simon, and A. Newell, began working with GPS in 1957. Since that time, GPS has been given a variety of different types of problems to solve, including sentence parsing, calculus problems, and verbal problems. The emphasis in research and development of GPS is on generality, i.e., GPS is to be a model of human problem solving capable of working with a variety of problems; and the greater the problem variety, the more general GPS will become. The kinds of problems for which GPS was originally designed are simple by most human standards, but they require intellectual effort by any

reasonable criteria. A typical problem is the missionaries-and-cannibals task. In this task, there are three missionaries and three cannibals who want to cross the river. The only way to cross the river is in a small boat with a capacity for two people. All six know how to operate the boat. The problem is that at any time there are more cannibals than missionaries on either side of the river, those missionaries will be eaten by the cannibals. The question posed is, how can all six get across the river without any missionaries being eaten? GPS successfully solves this problem, which is prototypic of the thinking-inference process found in reading scientific materials such as a mathematics textbook.

The problem-solving techniques of the GPS are based on the concept of purposive behavior. The GPS problem-solving techniques are organized by goals. By this, one means that the main function of the problem-solving techniques is to achieve the problem solution or goals. To do this, subgoals are generated in order to reach main goals. A goal is defined in the GPS program as a data structure that provides sufficient information to carry out problem-solving activities; i.e., a goal defines a desired state of affairs, the current situation, and a history of previous attempts to achieve the goal. GPS has four types of goal routines currently, and the necessity for other types of goal routines has not seemed to arise. These four types of goal routines are: (a) transform Object A into Object B, (b) reduce difference between Object B and Object A, (c) apply solution operator to Object A, and (d) select the elements of set S which best fulfill a criterion C.

For each of these goals, methods are generated to obtain the goal. The methods for a given goal are represented via a tree-structured list as shown in Figure 1. This tree is called a "discrimination net" because of contingent sorting capability. The terminal nodes of the tree are the methods for a goal. The solution selection is performed by discriminating, first at the top node, and then at each node in turn until arriving at a matching node. The learning process in GPS is the growth of these tree structures.

Just as methods for goal routines are represented by trees, the representation of real objects or concepts is also by trees. An object or concept may be any unit in the problem domain which we wish to utilize (i.e., an information unit). For example, the number of missionaries on the left bank, the number of cannibals on the right bank, and whether the boat is at the left bank, are all information units that represent objects. This object-concept representation problem is analogous to the ideas-identification process in reading an article. The major process of GPS in its attempt to solve problems is its tree searching. GPS must search for goals, it must search for methods to reach those goals, and it must access information units by tree searching.

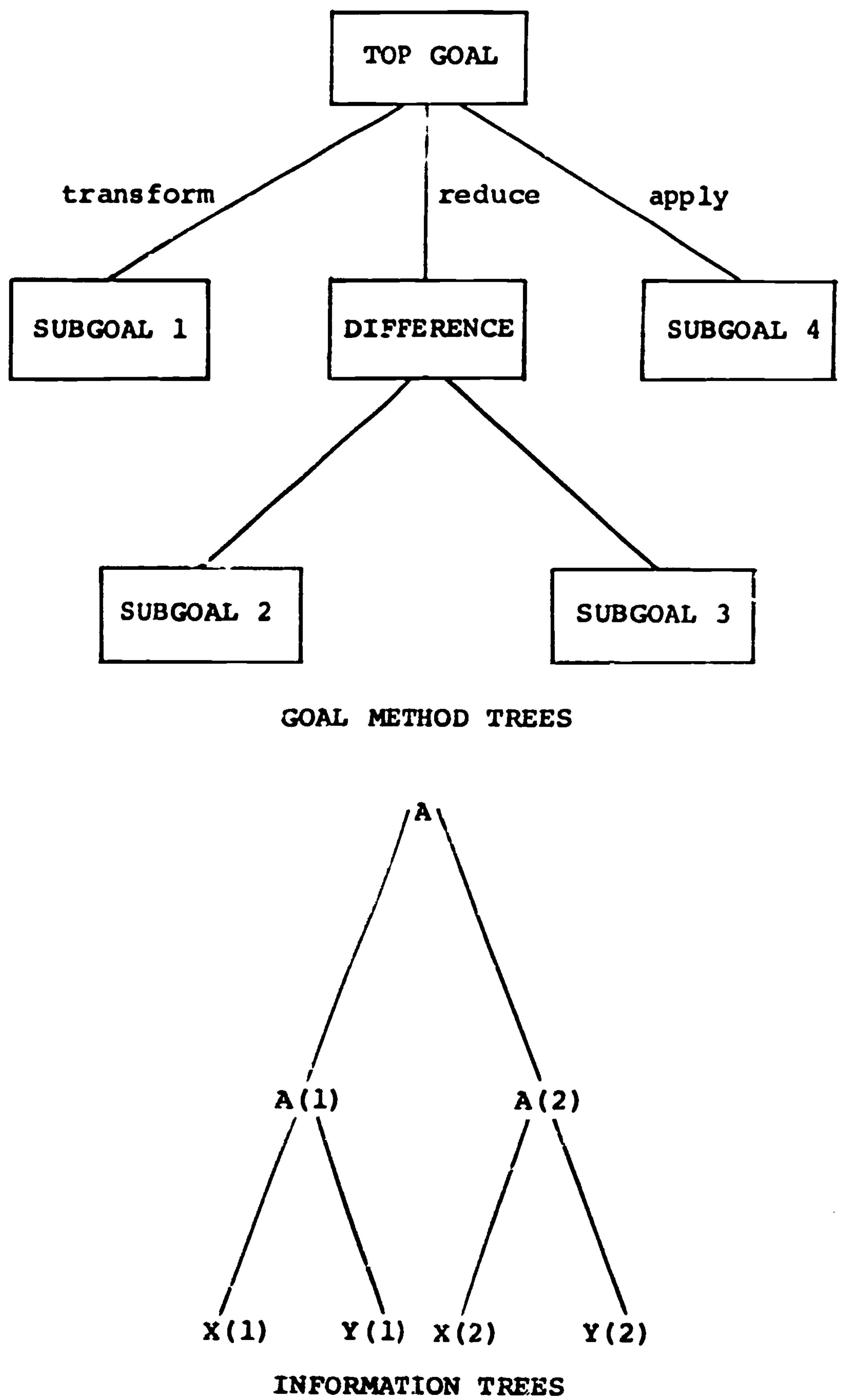


Fig. 1.--Examples of tree structures in GPS.

GPS uses a general technique called "means-ends analysis" to guide the search through the trees. Means-ends analysis involves subdividing the problem into easier subproblems. It is accomplished by taking differences between what is given and what is desired, i.e., between two objects or between an object and a class of objects. Thus, it is possible to see that the four subgoal routines mentioned above are an integral part of the means-ends analysis and the tree-searching process. Interestingly, one can clearly see how goal routines, tree-search processes, and means-ends analysis are useful components in attempting to understand purposive reading comprehension.

One of the important critical questions surrounding GPS and other computer model-problem solvers is the question of memory. Since objects, methods, and goals are all represented by a tree-structured list in GPS, essential memory structure and process are represented by tree structures and processes. The link from one node of a tree to another node is never broken in GPS; i.e., memory is perfect. But as Reitman (1965) has pointed out, human thinking is surprisingly interruptable. These interruptions affect memory in various ways. Input to memory may be disrupted or intermittent in nature (similar to interruptions while reading a novel). Using list-structure techniques or stochastic principles (Suppes, 1970), a representation of objects in human memory as a tree-structured list can be led to look like a tree with many broken limbs. Thus, GPS offers the potential to represent complex memory processes associated with reading comprehension.

The role of personality processes can be incorporated with the GPS.model (Simon, 1967). Simply, personality processes are conceptualized as interrupt commands that switch the GPS processor to personality subroutines. The personality subroutines can be represented by tree structures and are consistent with trait-state concepts found in personality theory (Spielberger, O'Neil, & Hansen, 1970). Thus emotional-personality processes found in reading (vicarious feeling states are commonly reported by readers of novels) can be represented with the GPS approach. We turn now to a consideration of interactive natural-language models.

Interactive Natural Language Models

Interactive Natural Language Models (INL) have developed out of the work from both machine-language translation and natural-language processing. The primary thrust of these investigations is a variety of attempts to develop sentence parsing and recognition techniques as well as semantic identification routines. Parsing is the procedure for syntactically classifying words in relation to other words. The most

perplexing problem in parsing is the resolution of ambiguity; this in turn leads into the issue of semantic identification. For example, a given word may have varying meanings depending on its syntactic placement--"run" may be a noun, verb, or adjective. It can mean to move the legs quickly, to be a candidate for office, to flow, to melt, to come undone, etc. Consulting any standard dictionary, one is likely to find at least one hundred possible entries. The problems of appropriate parsing and semantic identification still remain to be resolved, but interactive natural-language models offer techniques and processes that have great potential for understanding this special requirement within reading.

The essence of an interactive natural language (INL) model resides in the man-machine interaction. The INL model, as implemented within the computer, represents features essentially similar to a reader who is attempting to comprehend a passage or a listener who is interacting with another human being in a dyadic situation. The simplest and most well developed of these attempts is an INL model called ELIZA (Weizenbaum, 1966). The manner in which ELIZA will perform is determined by scripts. The scripts are data input to a general INL processor which accepts human natural-language input (usually typed), analyzes these inputs according to the script, and generates a response appropriate to the input. The most famous script, which simulates a Rogerian psychotherapist, is DOCTOR (Weizenbaum, 1967). Weizenbaum reports the following as a typical conversation. The responses made by ELIZA with a DOCTOR script are in upper case and the reader inputs are in lower case:

men are all alike.

IN WHAT WAY?

they're always bugging us about something
or other.

CAN YOU THINK OF A SPECIFIC EXAMPLE?

well, my boyfriend made me come here.

YOUR BOYFRIEND MADE YOU COME HERE?

he says i'm depressed much of the time.

I AM SORRY TO HEAR YOU ARE DEPRESSED.

it's true. i am unhappy.

DO YOU THINK COMING HERE WILL HELP YOU
NOT TO BE UNHAPPY?

i need some help, that much seems certain.

WHAT WOULD IT MEAN TO YOU IF YOU GOT SOME HELP?

perhaps i could learn to get along with my mother.

TELL ME MORE ABOUT YOUR FAMILY.

The ELIZA processor manages to carry on such conversations by performing what Simmons (1970) calls pattern-operation transformations. The learning process within INL models is a combination of pattern-operation transformations plus updated scripts. Almost all INL systems have some sort of pattern-operation rules but the rules and implementations differ from system to system. In general, pattern-operation means searching for a given pattern in the input sentence. If it is found, the INL processor performs a specified transformation on the given text in order to respond appropriately. ELIZA, which does not utilize parsing techniques, works as follows: (a) the input is read and inspected (the sentence decomposition process) for the presence of key words; and (b) if a key word is found, a response generation rule associated with that key word is invoked which combines a partially composed sentence with some portion of the input sentence. For example, if the script had defined "chall" as a key word with a transformation rule which said "i (Ø) chall (Ø)" and "what did you think after you (2) chall?" the system would react as follows:

INPUT: i just finished chall on reading.

OUTPUT: WHAT DID YOU THINK AFTER YOU JUST FINISHED CHALL?

The decomposition rule "i (Ø) chall (Ø)" is matched like a template against the input sentence after the key word "chall" is found. The (Ø) means all words between the specified words are acceptable. In this case, the input does match: "i (just finished) chall (on reading)," and the partly composed sentence "WHAT DID YOU THINK AFTER YOU (2) CHALL?" is combined with the second element of the input sentence ("just finished") to generate the final output.

In order to follow development in INL modeling, additional sentence decomposition elaborations are considered. First, the pattern-matching sentence routines can be made more complex via attempts to parse the sentence string. In addition, one can use ordered matching procedures by which one moves from key words to key phrases to total sentences for sentence decomposition and matching (Colby & Smith, 1969). For example, the sentence "jeanne chall wrote the definitive book on reading" can be initially checked for the key word "chall" and then such larger syntactic units as "chall wrote a definitive book" can also be identified subsequently. Thus, hierarchical

decomposition analysis allows for a systematic contingent process by which to automatically gain greater and greater comprehension of a single or multiple sentence input. It is proposed that a reader must learn skills similar to these in order to read complex sentences and passages.

In turn, contingent sentence decomposition leads into semantic identification routines. For example, as key words, phrases, and sentences are matched, these can be analyzed in terms of synonymous or alternative meanings. Also alternative interpretation can be flagged and utilized in subsequent semantic analysis. Attempts by Bobrow (1969) have been partially successful in developing conditional structures by which multiple sentences are identified and utilized in a game called "Detective." For the reading process, semantic analysis and multiple semantic interpretations are direct parallels of the cumulative comprehension process found in reading an article or book.

In regard to INL responding, each of the INL models has appropriately organized response generation routines as illustrated in the above example. The question format utilizes parts of the decomposed input sentence in order to construct the response, "WHAT DID YOU THINK AFTER YOU JUST FINISHED CHALL?" It can be conjectured that the information storage process during reading may be organized and stored in response-generation units similar to these INL response-generation routines. Given the purposive characteristics of reading, response-generation structures and routines could be one of the best representations of an organized human memory system that stores and structures during reading. Thus, INL models provide an operationalized approach to the reading-comprehension process; processes within the INL model should be considered as potential components for modeling the reading process.

Quantitative Instructional Models

A theme has developed within quantitative instructional models; namely, a computer-based theory of instruction, which provides a potential model of the reading-learning process. Two research traditions have contributed to the growth of this quantitative modeling approach for reading instruction: mathematical models of learning (Luce, Bush, & Galanter, 1963) and the development in computer-assisted instruction. Since computer-assisted instruction (CAI) has provided the greatest impetus to recent development of these quantitative models of instruction, it is appropriate to review the model proposed by Groen and Atkinson (1966) for optimizing the instructional-learning process.

CAI can be defined as a form of human-machine interaction whose goal is the efficient acquisition of desired

reading goals. In terms of the computing system, the pedagogical alternatives open to the reading researcher are as follows: (a) selection of an appropriate medium for presenting the reading content; (b) control of the rate of presentation; (c) control of the sequence of items within the reading content and accompanying questions; (d) concurrent recordings of all learning behaviors; and (e) a decision mechanism by which curriculum elements are presented to the student in a selected sequence and at a certain rate. This decision mechanism is commonly referred to as an instructional strategy, although the consideration of the selections of media is also included under this rubric. Optimization refers to the increase in efficiency found for one instructional strategy as opposed to another instructional strategy.

Before proceeding, it may be useful to characterize the instructional paradigm for CAI more explicitly (Groen & Atkinson, 1966). First, the reading passage or skill to be taught can be conceptualized as a set of presentation elements, P_i, which include both presentation information and questions. For each of these P_i elements there must exist one or more correct responses, R_i. These P-R pairs may be as simple as the presentation of the word "fun" with the requirement to pronounce it, or as complex as reading and answering the question, "How did the astronauts reach the moon?" after reading a thousand-word passage on the topic. As Figure 2 shows, an instructional session is started by initializing the learning history for a given student and determining which curriculum element to present to him (in essence, this is a specification of the current learning history or entry behaviors). Once the curriculum element has been presented to the student, a response is requested and is recorded within the CAI system. This response can be evaluated by a prestored set of answers and symbolic matching techniques. This, in turn, allows the system to update the learning history of the student. If the terminal element in the curriculum has not been reached, the system then branches back to the instructional strategy which determines the next curriculum element to be presented. If the instructional strategy is independent of the learning history of the student, it can be characterized as <u>static</u>. On the other hand, if the instructional strategy's selection is contingent on the previous learning history, the system can be referred to as <u>dynamic</u>--"response sensitive," in Groen and Atkinson's (1966) terms. The distinction between dynamic and static instructional strategies is highly important in that optimal solutions can be quantitatively approximated for either, but the best evidence today indicates that dynamic instructional strategies ultimately will provide for the individualization desired within reading instruction (Hansen, 1969).

For the purposes of developing a reading instructional model, one can note that a multivariate canonical form can be

7-34

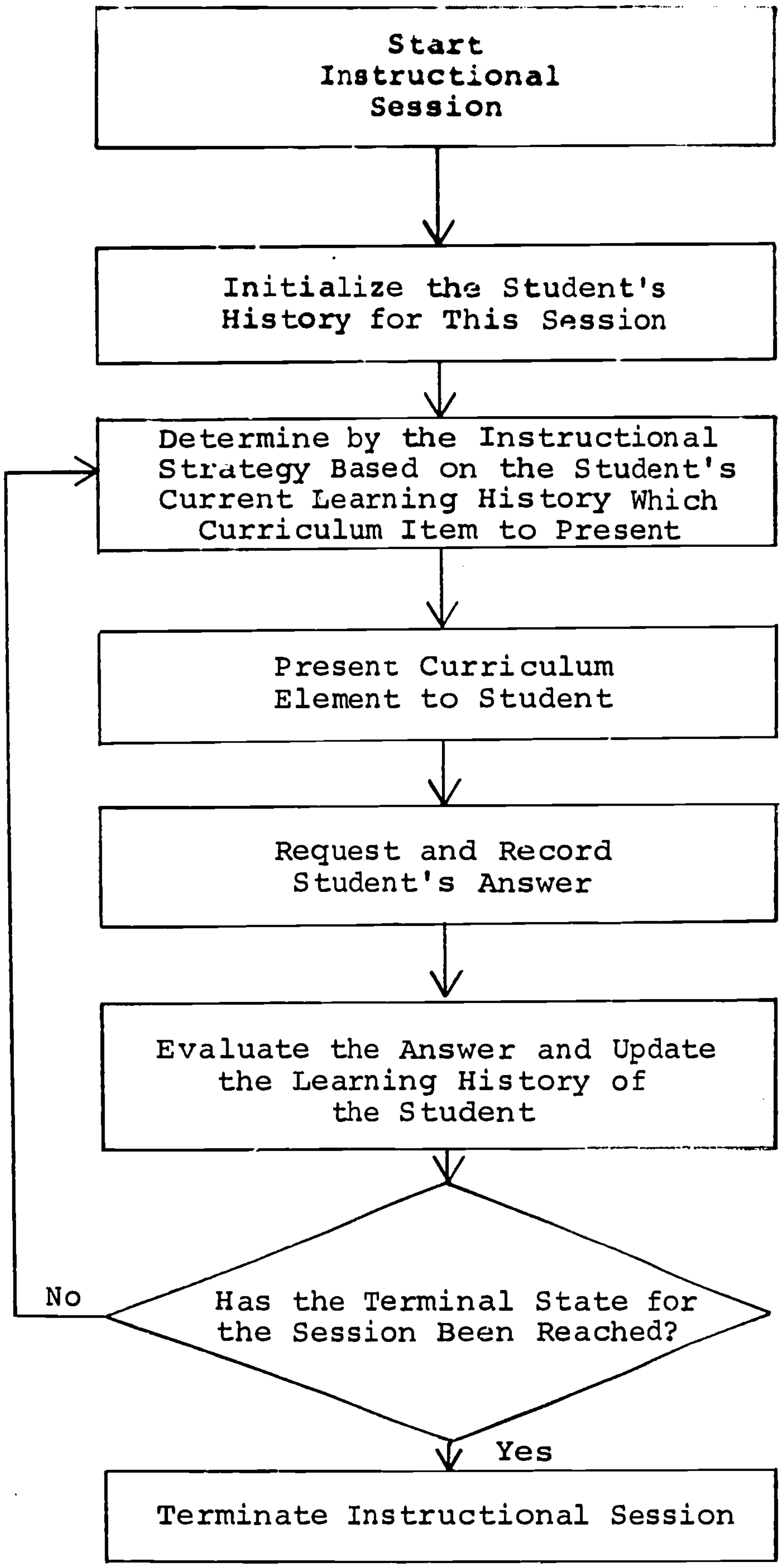


Fig. 2.--The instructional paradigm for CAI models.

used to characterize the history of the student; thus the desire to have a multivariate approach to reading is provided for within this CAI model. Secondly, statistical modeling concepts, like sufficiency and bias, can be utilized in evaluating the learning-history update process within this canonical CAI matrix approach. Therefore, one can foresee a new potential for these quantitative CAI learning models in that one can constantly update the reading competencies and skills, giving a clear representation of the reader's learning progress, especially in terms of prescribing the next instructional event within the reading instructional process.

The quantitative CAI learning model plus the GPS models and interactive natural-language models represent the principal developments in information processing and simulation research appropriate for consideration within reading models. We turn now to a more detailed consideration of information-processing subcomponents as these offer building blocks for generalized models of reading.

MODEL COMPONENTS FOR THE READING PROCESS

Information-processing concepts and specific computer procedures may hold great promise as potential building blocks for a complete model of the reading process and associated learning requirements. In this section, some of the more promising information-processing components will be reviewed, and illustrations offered as to how they can play a significant role within the reading modeling process. In order to provide some structure, these components will be categorized into the following three groups: (a) information structures, (b) process components, and (c) systems components.

Figure 3 illustrates the three conceptual categories involved in IP, as represented in this paper. They can be considered on two dimensions. First, the requirements for higher-level system components are defined by the lower-level components. For example, accessing an item on a tree-structured list (an information structure) requires a different process component than does accessing an item on an ordered table. The second dimension demonstrates that the invoking of a process or use of an information structure is determined from the top down. That is, if monitoring shows a need to delete information, the appropriate delete-process component must be chosen and this appropriate component will then manipulate the appropriate information structure.

Information-processing structures. Information structures can be defined as those procedures or programming techniques that allow for organization and association of information units. The information units should be considered representations or coding of symbols (numbers, words, phrases,

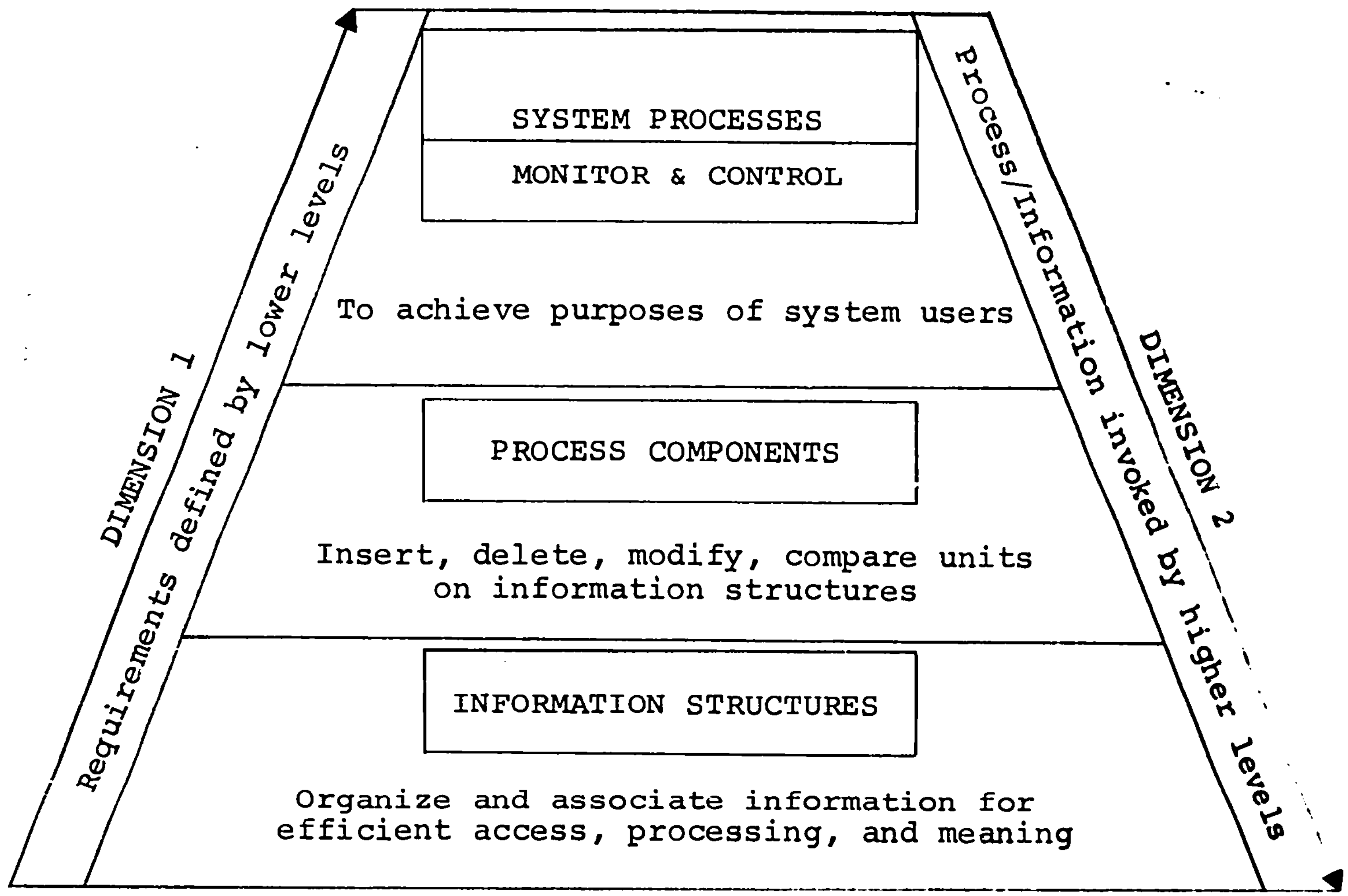


Fig. 3.--Component relationship in computer-based information processing.

concepts, images, etc.). The purpose of structuring information for organization and association is to provide for efficient storing, accessing, and processing. This paper will present four structures as follows: (a) list structures, (b) push-down list, (c) property list, and (d) symbol tables.

List structures can be thought of as the grouping of information units by associating or linking a given unit to another or others (Flores, 1966). Linkages are commonly established via the technique of inserting pointers in the list that provide directions to other information units in the list. The pointer may provide a direct link, a displacement, or a link to another list which may be searched. The pointer may also link either forward or backward on the list. This processing can be hierarchically organized, in that the pointers which establish linkages can be names for sublists nested therein. The real essence of list structures consists in the techniques and potential found within the establishment of linkages (Bloom, 1970; Slagle & Dixon, 1970). The primary advantage of list structures is that information units do not have to be sequentially ordered and processed, and linkage provides the potential for updating a particular list without having to rearrange all elements. For example, in reading comprehension, the adding of information on a concept can be handled via the establishment of a new concept list pertinent to the specific article, and then relating immediate comprehension to prior knowledge via pointer links. Thus, this provides a more explicit statement and greater flexibility in thinking through and conceptualizing what has commonly been referred to as the associative processes found within reading comprehension and thinking.

Push-down lists are a more sophisticated variation on list structures (Gauthier & Ponto, 1970; Hopcroft & Ullman, 1969). The most typical push-down list procedure involves stacking information elements in a queue such that the last item in would be the first item out. It should be noted, though, that circular or other organizing output algorithms can be inserted within push-down techniques. The primary reason for mentioning push-down lists is that they allow one to keep very careful track of the location and organization of data, such that it is output in an efficient and systematic manner. It can be conjectured that the reader needs to organize information while reading in a manner somewhat similar to a push-down list with more complex algorithms for organization and potential output, such as those directly related to the temporal plot features found within most children's stories.

Property lists are also a variation on list structures. The primary purpose of property lists is to provide a highly efficient structuring of distinctly different elements within the list such that one can match an input against given features on the property list. Property-list concepts are

commonly found within most discussions of letter-to-sound decoding skills, and therefore provide explicit statements of this property-matching process.

Lastly, symbol tables are a special case of a processing list (Flores, 1967). A symbol table consists of the alphabet and its appropriate location within the symbolic structure as employed within list-processing activities. By the use of symbol tables, one gains parsimony in processing time, in that one can use a symbol table and enter elements only once, as opposed to providing redundancy across all structures. For example, articles within English syntax could be considered an example of elements to be stored in a symbol table and appropriately marked for later reading output. As can be seen, there are direct analogues between these information structures as specified within information processing, procedures, and techniques and the reading-comprehension process and associated skills.

Process components. Process components refer to standard algorithms and associated techniques by which information is sorted, merged, and sophisticatedly manipulated. These routines offer modeling components directly relating to reading-comprehension skills. There are major process components within IP models. These are (a) interrupts, (b) indirect addressing, (c) parallel-serial, and (d) asynchronous processing.

Interrupts. The process of interrupts refers to the ability to signal the occurrence of an important event. Thus, rather than requiring constant monitoring, interrupt signals allow the management of complex parallel processing systems. In other terms, interrupts permit one to track the state of events without constantly monitoring each event. This allows for vastly improved efficiency of processing time. For the reading case, orthographic format considerations such as capitalization, periods, paragraphing, chapter headings, etc., can be thought of as interrupt signals that allow for appropriate organization; that is, they allow for appropriate information organization. Given that such formatting characteristics are thought to improve the ease of reading, one would have to consider an interrupt systems-process in order to explain their benefit.

Indirect addressing is a process by which hierarchical schemes can be achieved with increased speed and precision. More concretely, an indirect address is a tag by which an information element is located as opposed to actually searching for the specific element or its properties. In other terms, by indirect addressing, one refers to the address of the information element and not the element itself. Indirect addressing allows one to construct multiple levels by reference to multiple stages within a systematic hierarchy. Thus,

indirect addressing offers a clearer manifestation of hierarchical associative processes as has been conjectured as being necessary within the reading-comprehension process.

Serial and parallel processings are basic alternatives by which one can improve speed and complexity without subsequent losses in adequacy and monitoring. It would appear clear that reading comprehension would have to have parallel processing characteristics in order to account for the speed as well as the conceptual richness attained by an accomplished learner.

Asynchronous processing refers to the timing flexibility for finishing one step prior to executing the next step in a given routine; or, in other terms, asynchronous processing is one in which the amount of processing time for a given step is constant while asynchronous processing allows for variability. Thus, for the acquisition of reading skills, asynchronous processing would provide one conceptual component allowing for increases in reading speed as well as such behaviors as scanning.

In considering the nature of interrupts, indirect addressing, parallel-serial processing, and asynchronous processing, one can see subcomponents by which the reading process can be explicit, while explaining increases both in speed as well as complexity. These would be especially important features if one were building a model for speed reading.

Systems processes. As information structures and process components are aggregated and linked in various serial fashions, one starts to consider some of the total information-systems processes (Uttal, 1967). System components are those general methods by which information structures may be acted upon. They, being essentially programming in nature, may be contrasted with process components which are more detailed, sometimes hardware mechanisms for handling information processing. In this regard, six basic processes are worth consideration in terms of thinking of building a comprehensive reading model: (a) monitoring, (b) closed subroutines, (c) reentrant routines, (d) recursive routines, (e) look-ahead-behind procedures, and (f) error detection-correction procedures.

Monitoring is the concept in which one supervises, controls, and checks upon the operation of another task. In the computer area, this is often called the master-slave relationship between tasks. An example of this relationship in reading would be the visual scan and decoding process, typically being unconscious in nature for a skilled reader, having a subordinate, slave-like contact with the conceptual processing in the comprehension component.

Closed subroutines are processes by which a whole sequence of to-be-executed steps can be accessed via just one command. As opposed to closed subroutines, open subroutines are ones which are executed as one encounters them in a sequential fashion. Closed subroutines are valuable in that one increases the process speed by the efficient calling and multi-path execution. Secondly, one also saves extensively, in computer applications, on memory storage. Thus, it would appear that many of the syntactic-analysis processes proposed for various language-reading models could be viable only through such a subcomponent as a closed subroutine. Thus, closed subroutines would contribute to both increased efficiency and multiple reading acts during the same time period.

A reentrant subroutine is one in which two or more tasks can use the same routine any time without worrying about whether the reentrant routine is currently being executed by either. In other words, if a reentrant routine is being executed, the execution may be interrupted so that a second task can be implemented, and this second task can call the reentrant routine without any errors being caused. This mechanism is accomplished by not allowing the routine to modify itself and by the use of a push-down list to separate and keep track of the data being operated upon at the different points in time. For reading, reentrant subroutines could account for the shifts to detailed decoding of proper names while reading for comprehension as in a novel.

A recursive subroutine is one which during its execution must recall itself one or more times. This creates vested levels of execution. Recursive routines are not to be confused with reentrant routines. As explained above, reentrant routines are at the disposal of several tasks while a recursive routine is at the disposal of itself. A concrete example from the reading process may help illustrate this point. One is reading a paragraph and, thus, is "in" the paragraph routine. Within that paragraph is a quote of some length which involves three paragraphs. When the reader encounters the quoted paragraph, he must "recall" the paragraph routine although he is already "in" it. The push-down list is a necessary structure to keep track of the nested data and execution of recursive routines. Remembering that push-down lists are a last-in/first-out structure, one can see in the example that the last process started, that of reading the quoted paragraph, will be the first one completed.

Look-ahead-behind procedures are mechanisms by which to trace one's processing of a series of informational events. Also they allow the anticipation of future events. Thus, in essence, they provide the system with a vastly improved monitoring capability. In reading, look-ahead-look-behind procedures can account for both regressive rereadings and

scanning in the more sophisticated forms of reading. Thus, in essence, speed reading becomes a question of formalizing our concepts of monitoring. Look-ahead-behind systems procedures would also allow for variable speed rates as well as some possibilities for implementing the notion of reading with a specific purpose.

Error messages (Flores, 1967) refer to systems responses that have identified illegal or unforeseen events that do occur and cannot be processed via available routines. Error messages have importance in that they determine the state of a given process when it has started to fail, and they also are essential for quick recovery from failure states. In addition, the error message can contain content which allows the human being to consider alternative ways of "debugging" the specific error. Thus, error messages become a mechanism by which self-learning can take place. Error messages could account for such phenomena as regressive rereadings.

While these information-processing components primarily exist with computing theory and operation, they do offer explicit elements or processes for future developments of reading models. We turn now to a brief review of how these components and associated information-processing research have progressed.

EMPIRICAL RESEARCH FINDINGS: THE STATE OF THE ART

Computer Simulation Models

The research reported here is concerned with the construction of information-processing models underlying human cognitive processes, the closest analogue to reading. The major aim of this research and modeling is with the programming of computers to perform cognitive tasks in a manner equivalent to that of a human performing the task. It is an attempt to simulate human information processing.

The general problem solver (GPS) is an attempt to model human problem solving (Ernst & Newell, 1969; Newell, Shaw, & Simon, 1960). The emphasis in the research on GPS is the generality of problems the computer program can solve. Stress is on the number of different types of problems a GPS can handle, and the quality of problem solving exhibited by the program is of only secondary importance to the authors of GPS. The names given to the various problems that GPS has successfully attempted give a clue to the variety of problems it has handled; these are: (a) missionaries-and-cannibals task, (b) numeral integration, (c) tower of Hanoi, (d) proving theorems in the first-order predicate, (e) calculus, (f) father-and-sons task, (g) money task, (h) three-coins puzzle, (i) parsing sentences, (j) bridges of Konigsberg, (k) water-jug

task, and (1) letter-series completion. For each of these tasks, GPS has generated an acceptable set of protocols that, when matched with protocols from human subjects, allowed for acceptance of the Turing Test.

A computer program model called the Elementary Perceiver and Memorizer (EPAM) was constructed to model elementary human symbolic learning processes (Feigenbaum, 1963). The EPAM Program is concerned with a model of verbal learning. The basic experimental task is presentation with either serial or paired-associate paradigms. The task for the human subject or EPAM is to learn the association between listed pairs or unique pairs. For the verbal-learning tasks, EPAM produces protocols almost equivalent to human protocols. All of the interference and primacy-recency effects can be found in the EPAM data. One of the special problems of this research is the determination of whether association takes place between the symbols or between tokens of these symbols. This has been pointed out by the fact that EPAM cannot learn a serial list in which the same items occur twice; that is, it cannot distinguish between the first and second occurrences of the item. To resolve this problem, the model was formulated to have chains or links for token associations with symbols. EPAM has successfully modeled the sight-word-reading process.

The computer modeling of concept formation has also been attempted (Hunt & Hovland, 1963; Hunt, Marin, & Stone, 1966). In the typical concept formation experiment, a human subject is confronted with a series of stimuli which are given a particular name and another series of stimuli which are either given another name or a series of different names. Therefore, the first set might be called dogs, and the second either not dogs, or birds, or cats. The task for the subject is to determine the particular name and set of the stimuli. While the model seems to simulate human data where there are few attributes or concepts, there are difficulties in extending the task to more complicated concepts or hierarchies of concepts. One of the obstacles may be that the typical concept for an experiment should be considered as involving three processes: memory, recognition, and problem solving. It may be that concept learning should be considered as consisting of these three processes rather than as a unitary process for any task.

Selfridge and Neisser (1963) have created a computer model of pattern recognition that distinguishes between objects and their relationships in the environment. At the present time, this program, when making distinctions, makes only 10 percent fewer errors than human readers. At the same time, it cannot handle several types of tasks that human readers can handle. The three types of problems identified by Selfridge are segmentation, hierarchical learning, and future generation; that is, the characters must be fed in one at a

time as the simulator is unable to segment continuous material. Further, the program learns on one level only. It would be desirable for a model to use its past experience in recognizing new stimuli. Finally this program and other similar programs do not have the capability to generate new features to match against new stimuli. That is, if the features are not preprogrammed, they cannot be used to test against features of new stimuli. Other researchers (Uhr & Vossler, 1963) have created simulators that evaluate, generate, and adjust operators for new features. This was performed in the effort to distinguish new features of stimuli. Progress continues at a rapid rate in terms of preparing new versions of computer simulation models.

Semantic networks were introduced by Quillian (1966, 1969). Generally speaking, a semantic information structure is an organization of units of information in terms of their meaning and mutual relationships. A given unit may refer to other units, which in turn may refer to still other units. The reference levels are not limited. In this way, a tree of references and cross references is generated with definitions and relationships. Quillian has called the unit, which has subunits as parts, the superset. Properties of the superset are considered to be directly transferable to subunits; thus, the hierarchical relationships found in reading comprehension are given representation.

Collins and Quillian (1969) have found evidence that human memory has the same kind of hierarchical structure as that of the semantic networks described here. When measuring reaction times to forced-choice questions (yes or no) with varied levels of supersets, they found that reaction times consistently increased along the dimension of subset to supersets. This has provided an operational definition of the concept of semantic distance.

Automata theory is still another possible source of modeling for reading. Essentially, automata refers to systems which appear to be self-acting. Thus, automata may be artificial systems (such as computers) or natural systems (such as people). These self-acting systems are considered to consist of n input symbols, p internal states (consider an electronic mechanism for which we do not know the circuitry but can suggest its possible states), and r output symbols. Given that we know the inputs and outputs, we are interested in the internal states. We can consider the internal processes for reading to be a language recognizer (Hopcroft & Ullman, 1969). That is, it will pass through various states to allow recognition of symbol strings for correspondence to language correctness and meaning. As another example, we may consider the automata to have capabilities of self-diagnosis and self-repair (error detection and correction). This was, in fact, addressed by the founder of automata theory, John von Neumann,

some twenty years ago (1966). Von Neumann developed a parsimonious theory accommodating both natural and artificial systems in terms of reliability. This brief introduction to automata theory would be severely lacking if we did not mention the close connection between mathematical logic and automata; in fact, von Neumann spoke of a "logical theory of automata." The current literature exemplifies the logical basis by use of algebraic group theory and combinatorial analysis (Arbib, 1968; Booth, 1967); thus, the current automata models represent a merging of computer-simulation techniques with the formal, axiomatic features of math models of the learning process.

Interactive Natural-Language Models

Possibly the simplest of the natural-language processing (NLP) attempts is a program called ELIZA (Weizenbaum, 1966, 1967). This NLP model has been utilized successfully with Rogerian psychotherapy dialogues, detective dialogues, and physics problem solving. The preparation of scripts for the dialogues remains a major logistic obstacle.

Another NLP project of interest is Colby's simulations of belief systems (Colby & Enea, 1967, 1968). The goal of this project is to achieve a conversation machine which can accumulate, during an on-line conversation, belief statements held by the human. The purpose of such belief accumulation is to use these statements in analyzing input to generate appropriate responses. Colby's programs originally used a set of pattern-operation rules much like those of ELIZA. More recently, more complex methods have been developed (Colby & Smith, 1969; Colby, Tesler, & Enea, 1969). The newer techniques augment the word-pattern matching by predicting characteristics of responses to the system's questions. For example, a "why" question predicts a "because" type response and a "yes-no" type question predicts an affirmative or negative response. This allows the system to be more specific in the next question. Another new feature allows the NLP system to store pertinent facts about the subject to avoid conversation errors as in the text below.

> when my father died my mother was sick a long time.
>
> TELL ME MORE ABOUT HIM.
>
> my father was a writer. he was kind but rather cynical . . .
>
> HOW IS HE?
>
> he is dead.

This is a passage, reported by Colby and Enea (1967), generated before the system could store and use the fact that the father was dead. The most recent addition to the belief system is a feature which stores and uses relationships between concepts. The relationships thereby characterize a belief in terms of its intensity, credibility, etc. Rules of inference are then used to operate upon these data (for example, A implies B) to generate relevant conversation.

A second belief system is reported by Abelson (Abelson & Carroll, 1965; Abelson & Reich, 1969). This system is based on the logical relations between concepts. It uses inductive logic with these data to accept or reject statements which are in accordance with its beliefs.

Carbonell (1970) has reported an INL prototype system for computer-assisted instruction, SCHOLAR. SCHOLAR is based on the use of information structures which are in the form of networks of facts, concepts, and procedures. Each element in the network is a unit of information which defines a word or event. The elements are associated by linking them in multilevel tree lists. The resulting networks operationally represent meaning because of the hierarchical associations. Thus, the networks can be said to be "semantic" networks. By utilizing this symbolic information network, SCHOLAR is able to generate the material presented to the student, the questions to be asked, and the corresponding expected answers.

The Information for Vocational Decisions (ISVD) is a computer-based system for providing career development. The project is a product of several members of the Harvard Graduate School of Education (Tiedeman, 1968). One of the goals of the project was to allow an inquirer to make career decisions by obtaining vocational information from a machine. The inquiry was to be in the inquirer's natural language since this reflected his internal world (Ellis, Pincus, & Yee, 1968). A great deal of empirical research remains necessary before these INL models can be considered acceptable.

Quantitative Instructional Models

From an empirical point of view, there has been limited experimental work on instructional models. The primary effort has been led by the Stanford group. Atkinson, in collaboration with Dear and Silberman (Dear, Silberman, Estavan, & Atkinson, 1967), performed one of the early optimization studies using a word paired-associate paradigm. This study indicated that a memory process was necessary in order to provide for the retention requirement within paired-associate learning. Laubsch (1970) utilized a phasing design for the learning of a Swahili vocabulary; this optimization model utilized individual parameters for word difficulty as well as

individual difference parameters for learning. While at Stanford, Hansen (1969) performed a spelling study which looked at four different instructional strategies. The result of a criterion item-drop-out strategy using a whole list approach proved to be optimal. Within all of this line of research, it is necessary to utilize a real-time computing capability in order to closely relate a student's learning history to the appropriate item-selection strategy.

Following the initial work of the Stanford group in word problems in mathematics (Suppes, 1964), the Florida State University group (Hansen, Gallagher, & Burks, 1969; Hansen, Gallagher, McCune, & Lavin, 1970) has constructed CAI reading materials for grades 1-6. These materials use a level-of-difficulty optimization concept; that is, a student is branched to an appropriate level of difficulty so that his average correct responding level is somewhere between .60 and .80. In addition, a reading-comprehension question taxonomy was developed. The analysis of the data of the question types indicates, at this point, that there are considerable variations in difficulty as one moves from informational recall through inference making and on into evaluational questions.

In a recent study performed at Florida State University by Rivers (1971), regression-modeling techniques were utilized to predict the need for additional remedial materials by utilizing the variables of proportion of correct response, latency, and state anxiety. Rivers was able to demonstrate that the optimization group was 20 percent better than a linearly sequenced control group. These results are promising both in preliminary results and in the range of models now under consideration for optimization.

As a variant on computer-assisted instruction, the research group at System Development Corporation (Coulson, 1967) and the Pittsburgh group (Glaser, 1969) have been investigating quantitative instructional procedures within computer-managed instruction. Organizing reading curricula within a hierarchical structure based on Gagné's (1970) task-analysis procedures, they have been processing a number of students through these reading materials. Preliminary results indicate that there are optimal learning hierarchies which can be tapped via the diagnostic evaluation and learning-prescription procedures found within computer-managed instruction. While this effort is only in its infancy, one can anticipate a rapid growth in this particular variation of computer instructional models.

FUTURE DEVELOPMENTS

By this point, one trusts that this paper has convinced the reading researcher that information-processing concepts,

especially considered from a component and subcomponent viewpoint, offer great promise for addressing the complexities of modeling the reading process. During the coming decade, one can anticipate that there will be an accelerating research effort in the three primary information-processing areas; namely, the General Problem Solver, interactive natural-language models, and quantitative instructional models. One can look forward to many more empirical reports that will verify both the promise of subcomponent processes within each of these three modeling developments and refinements within the theories of deficiencies are identified. At this point, I wish to highlight some important aspects of reading comprehension that have been almost totally overlooked by the field.

First, there appears to be increasing evidence for the requirement of having some sort of internal self-inspection capability that represents the monitoring processes found in skillful readers. Unfortunately, the nature of this monitoring process has received little or no attention. By monitoring, one explicitly means the process by which the reader identifies ideas, processes them, and decides whether he is comprehending according to some self-specified criteria. Behaviorally, such phenomena as regressive rereading of passages, selective processing of concepts within a passage, as well as the phenomena of rereading when preparing for examination directly relate to the requirement for an internal monitoring process. In essence, an internal monitoring process, if thoroughly understood, may give us better understanding of what we mean by reading with a special purpose.

As a second underdeveloped problem area in reading, there appears to be clinical evidence that readers are capable of employing error-detection techniques involving skills that allow for such phenomena as adjustments in reading rate as well as the kind of information stored as the outcome in reading. Unfortunately, in learning psychology, little attention has been given to studying how people learn to "debug" their own real-world problem solutions, or how the skills of error analysis are applied. This is a most unfortunate state, and it is the contention of this paper that considerable research effort will be needed if a comprehensible generalizable model of reading is to evolve during the coming decade.

Lastly, the work on instructional quantitative models has identified the requirement for instructional strategies. As a complement, it seems more appropriate that readers be allowed to evolve strategies as they start and proceed through long passages, such as a novel. These strategies undoubtedly will address themselves to issues like the trade-off between precise decoding vs. scanning and, it is hoped, have some prediction concerning self-determined reading rates as well as some ideas as to the organization of serial and parallel processing of the comprehended information. Thus, the research

challenges from a modeling point of view can be considered monumental. On the other hand, by identifying major problem areas, one is allowed to attempt to make research progress that can have both theoretical and empirical benefits.

REFERENCES

Abelson, R. P., & Carroll, J. D. Computer simulation of individual belief systems. American Behavioral Scientist, 1965, 9, 24-30.

Abelson, R. P., & Reich, C. M. Implicational molecules: A method for extracting meaning from input sentences. Proceedings of the International Joint Conference on Artificial Intelligence. Washington, D.C., 1969. Pp. 641-647.

Arbib, M. A. Automation decompositions and semigroup extensions. In M. A. Arbib (Ed.), Algebraic theory of machines, languages, and semigroups. New York: Academic Press, 1968.

Atkinson, R. C., & Paulson, J. A. An approach to the psychology of instruction. Psychological Bulletin, in press.

Bloom, B. H. Space/time trade-offs in hash coding with allowable errors. Communications of the Association for Computing Machinery, 1970, 13, 422-426.

Bobrow, D. G. Syntactic analysis of English by computer--A survey. Proceedings of Fall Joint Computer Conference, 1969, 24, 365-387.

Booth, T. Sequential machines and automata theory. New York: Wiley, 1967.

Carbonell, J. R. Mixed-initiative man-computer instructional dialogues. Prepared under ONR Contract N00014-69-C-0233, Bolt Beranek & Newman, Inc., Cambridge, Mass., 1970.

Colby, K. M., & Enea, H. Heuristic methods for computer understanding of natural language in context-restricted on-line dialogues. Mathematical Biosciences, 1967, 1, 1-25.

Colby, K. M., & Enea, H. Inductive inference by intelligent machines. Scientia, 1968, 103, 669-680.

Colby, K. M., & Smith, D. C. Dialogues between humans and an artificial belief system. Proceedings of the International Joint Conference on Artificial Intelligence. Washington, D.C., 1969. Pp. 319-324.

Colby, K. M., Tesler, L., & Enea, H. Experiments with a search algorithm for the data base of a human belief structure. Proceedings of the International Joint Conference on Artificial Intelligence. Washington, D.C., 1969. Pp. 649-654.

Collins, A. M., & Quillian, M. R. Retrieval time for semantic memory. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 240-247.

Coulson, J. E. An instructional management system for public schools. Santa Monica, Calif.: Systems Development Corporation, 1967.

Dear, R. E., Silberman, H. F., Estavan, D. P., & Atkinson, R. C. An optimal strategy for the presentation of paired-associate items. Behavioral Science, 1967, 12, 1-13.

Ellis, A. B., Pincus, M. E., & Yee, P. Getting a guidance machine to understand English. ISVD Project Report No. 14, Graduate School of Education, Harvard University, 1968.

Ernst, G. W., & Newell, A. GPS: A case study in generality and problem solving. New York: Academic Press, 1969.

Feigenbaum, E. A. The simulation of verbal learning behavior. In E. A. Feigenbaum & J. Feldman (Eds.), Computers and thought. New York: McGraw-Hill, 1963.

Flores, I. Computer programming. Englewood Cliffs, N. J.: Prentice-Hall, 1966.

Flores, I. Computer software. Englewood Cliffs, N. J.: Prentice-Hall, 1967.

Gagné, R. M. The conditions of learning. (2nd ed.) New York: Holt, Rinehart, & Winston, 1970.

Gauthier, R. L., & Ponto, S. D. Designing systems programs. Englewood Cliffs, N. J.: Prentice-Hall, 1970.

Glaser, R. Evaluation of instruction and changing educational models. In M. C. Wittrock & D. Wiley (Eds.), Evaluation of instruction. New York: Holt, Rinehart, & Winston, 1969.

Groen, G., & Atkinson, R. C. Models for optimizing the learning process. Psychological Bulletin, 1966, 66, 309-320.

Hansen, D. N. Current research development in computer-assisted instruction. Proceedings of the Inaugural Conference of the Scientific Computation Center and the Institute of Statistical Studies and Research. Cairo University, 1969. Pp. 718-740.

Hansen, D. N., Gallagher, P., & Burks, A. A rural county computer-related instructional technology project. Wakulla County USOE Title III Project, 1969. Computer-Assisted Instruction Center, Florida State University, Tallahassee, Fla.

Hansen, D. N., Gallagher, P., McCune, L., & Lavin, B. A rural county computer-related instructional technology project. Wakulla County USOE Title III Project, 1970. Computer-Assisted Instruction Center, Florida State University, Tallahassee, Fla.

Hilgard, E. R., & Bower, G. H. Theories of learning. (3rd ed.) New York: Appleton-Century-Crofts, 1966.

Hopcroft, J. E., & Ullman, J. D. Formal languages and their relation to automata. Reading, Mass.: Addison-Wesley, 1969.

Hunt, E. B., & Hovland, C. I. Programming a model of concept formation. In E. A. Feigenbaum & J. Feldman (Eds.), Computers and thought. New York: McGraw-Hill, 1963.

Hunt, E. B., Marin, J., & Stone, P. J. Experiments in induction. New York: Academic Press, 1966.

Laubsch, J. H. An adaptive teaching system for optimal item allocation. Technical Report 151, Institute for Mathematical Studies in the Social Sciences, Stanford University, 1970.

Luce, R. D., Bush, R. R., & Galanter, E. (Eds.) Handbook of mathematical psychology. New York: Wiley, 1963.

Newell, A., Shaw, J. C., & Simon, H. A. Report on a general problem-solving program for a computer conference. Information Process: Proceedings of the International Conference of Information Processing. Paris: UNESCO, 1960. Pp. 256-264.

Quillian, M. R. Semantic memory. Unpublished doctoral dissertation, Carnegie Institute of Technology, Pittsburgh, 1966.

Quillian, M. R. The teacher language comprehender: A simulation program and theory of language. Communications of the Association for Computing Machinery, 1969, 12, 459-476.

Reitman, W. R. Cognition and thought, an information processing approach. New York: Wiley, 1965.

Rivers, L. C. A methodology for maximizing performance and minimizing time on computer-assisted instruction. Unpublished doctoral dissertation, Florida State University, 1971.

Selfridge, O. G., & Neisser, U. Pattern recognition by machine. In E. A. Feigenbaum & J. Feldman (Eds.), Computers and thought. New York: McGraw-Hill, 1963.

Simmons, R. F. Natural language question-answering systems. Communications of the Association for Computing Machinery, 1970, 13, 15-30.

Simon, H. A. Motivational and emotional controls of cognition. Psychological Review, 1967, 74, 29-39.

Slagel, J. R., & Dixon, J. K. Experiments with the M & N tree-searching program. Communications of the Association for Computing Machinery, 1970, 13, 147.

Spielberger, C. D., O'Neil, H. F., Jr., & Hansen, D. N. Anxiety, drive theory and computer-assisted learning. Technical Report 14, Florida State University, 1970.

Suppes, P. Problems of optimization in learning a list of simple items. Technical Report 57, Institute for Mathematical Studies in the Social Sciences, Stanford University, 1964.

Suppes, P. Probabilistic grammars for natural languages. Technical Report 154, Institute for Mathematical Studies in the Social Sciences, Stanford University, 1970.

Tiedeman, D. V. The information system for vocational decisions: Description, subsequent development, and implications. ISVD Project Report No. 166, Graduate School of Education, Harvard University, 1968.

Uhr, L., & Vossler, C. The pattern recognition program that generates, evaluates and adjusts its own operators. In E. A. Feigenbaum & J. Feldman (Eds.), Computers and thought. New York: McGraw-Hill, 1963.

Uttal, W. R. Real-time computers; techniques and applications in the psychological sciences. New York: Harper & Row, 1968.

von Neumann, J. Theory of self-reproducing automata. Urbana: University of Illinois Press, 1966.

Weizenbaum, J. ELIZA--A computer program for the study of natural language communications between man and machine. Communications of the Association for Computing Machinery, 1966, 9, 36-45.

Weizenbaum, J. Contextual understanding by computers. Communications of the Association for Computing Machinery, 1967, 10, 474-480.

1-17 | 7-73

SUCCESS AND FAILURE IN LEARNING TO READ: A CRITIQUE OF THE RESEARCH

S. Jay Samuels

University of Minnesota

INTRODUCTION

Why some students learn to read with facility while others, with similar intellectual capacity and apparently adequate instruction, have difficulty in acquiring this important skill has been a focus of research inquiry for some time. Numerous attempts have been made to identify possible causes and correlates of reading difficulty. Explanations of causes and correlates of reading difficulty have included congenital word blindness (Hinshelwood, 1917), mixed cerebral dominance (Orton, 1937), difficulty in integrating information in different sensory modalities (Birch & Belmont, 1964), poor associational learning ability (Otto, 1961), poor memory (Senf, 1969), and lack of attention (Lahaderne, 1968), to name just a few. Cause-effect explanations of reading difficulty have varied on the independent-variable side from single to multiple factor causes and on the dependent-variable side from single to multiple effects. Wiener and Cromer (1967) have provided a useful method for classifying the various explanations of reading difficulty.

Because it is important to know why some students succeed while others fail in learning to read, we can expect continued research on this topic. This paper has several objectives relevant to future investigations of reading success and failure, as well as to the interpretation of research already completed on this topic. First, this article will criticize a number of popular explanations of reading difficulty and their methods of research. Second, it will present a brief review of literature on components of associational learning that are important in learning to read. Third, it will present a model of associational learning derived from current conceptualizations in cognitive psychology. This model serves as a basis for further work on reading difficulty. Combined with the model is an approach to conducting research that can overcome some of the methodological problems outlined in the first part of the paper.

Before starting the paper, however, it is important to caution the reader that the model of associational learning is

neither a model of the reading process nor of learning to read and should not be viewed in either light. Although associational learning is involved in learning to read, by no stretch of the imagination can the model presented here be considered a model of reading.

CRITICISMS OF CURRENT EXPLANATIONS OF CAUSES OF READING DIFFICULTY AND THEIR METHODS OF RESEARCH

Labels as Pseudo-Explanations

In answer to the question as to why some students do less well in reading than may be expected from indicators of their intellectual ability, increasingly we are hearing that the students have learning disabilities, that there is neurological impairment, or the students have dyslexia. By identifying the problem, giving it a name, and putting the students into a diagnostic category, many educators and psychologists delude themselves into believing they have gained insight into the causes of the problem (Staats & Staats, 1963, p. 14). Labels delude us into believing we understand the factors which underlie the student's failure to learn. If we ask, "Why is the student failing in reading," we often get the answer, "He is unable to learn because he has a learning disorder." This answer tells us nothing about the actual sources of difficulty the students are experiencing. In fact, the answer implies circular reasoning since it is largely because of the presence of academic retardation that the label is ascribed.

Actually, labels such as learning disorder, dyslexia, etc., provide no useful information as to why students are failing. There are numerous reasons why a person may have trouble learning to read. To mention just a few of the possibilities, the student may be inattentive, he may not know where to focus attention, he may be unable to discriminate distinctive features embedded within complex visual and auditory stimuli, he may be unable to recall these stimuli, and he may be unable to associate these auditory and visual stimuli. The labels do not in any way indicate where the student is having trouble nor do they provide a clue as to how the difficulty may be overcome.

By labeling a student as "brain damaged," "neurologically impaired," "learning disabled," not only is the student placed in a category, but the category name implies that the cause of the problem is known. A diagnosis of learning disability is often made by systematically ruling out other factors. If, for example, the diagnostician can rule out emotional problems, mental retardation, inadequate instruction, and the like as causes of the learning problem, the student

may be identified as one with a reading disability. Diagnosis-by-elimination, followed by placing the student in a category which implies that the cause of the problem is known, is scientifically untenable.

There is an additional problem connected with using labels such as "learning disability," "dyslexia," etc., to explain why students fail in reading. Developmental dyslexia is thought to be an organically determined cerebral defect leading to difficulty in learning how to read (Critchley, 1964). Terms such as "brain damage," "neurologic impairment," and "minimal cerebral dysfunction" have all been used somewhat interchangeably in the literature on learning disabilities and imply a brain which is not functioning properly (McCarthy & McCarthy, 1969, p. 15). If neurological damage were the cause of the difficulty, we would expect to find some degree of parity among nations in terms of the number of people in each of the countries who fail to read because of learning disabilities. Instead, we find that reported cases of reading failure due to learning disabilities are twelve times higher in the United States than in Japan and twenty-two times higher in Austria than in Japan. With figures this discrepant from one another, the problem seems to be one of diagnosis and classification.

Sources of Unreliability in Classifying Students

The problems confronting the researcher in accurately diagnosing and classifying students into a reading disability category are crucial in evaluating this body of research. A reading disability is said to exist when, despite adequate instruction, absence of emotional problems which may interfere with learning, adequate attendance, a cooperative child, and absence of sensory impairment, there is a discrepancy between the reading achievement level and some measure of potential ability. Samuels (1970c) has argued that assumptions such as "adequate instruction" are probably false, especially in light of our lack of knowledge of learning hierarchies (Gagné, 1962) and optimal skill sequencing in reading. There are a number of important skills and concepts essential for reading which seldom are included in a course of instruction either because the teacher assumes the students have already mastered these or because the teacher is unaware that they are important.

Another problem in accurate diagnosis and classification into a reading disability category is in determining the size of the discrepancy between potential and actual achievement. Reed (1970) has pointed out that expectancy level varies with the formula used to compute potential achievement. Thus, a student may or may not be placed in a

reading-disability category depending on which formula is used to compute the reading achievement expectancy level.

Two other sources of unreliability are found in the reading achievement tests and the intelligence tests used for purposes of making diagnostic classification of students. The same pupil, given different reading achievement tests, may obtain reading grade-equivalent scores that are remarkably discrepant from one another. Similarly, the same student, given several different intelligence tests, may obtain scores that are quite different from each other. A study of Jerrolds, Callaway, and Gwaltney (1971) gave the same 50 students three different reading-achievement tests and three different intelligence tests. The students were then classified into three reading categories: nondisabled, disabled, severely disabled. Table 1 clearly illustrates the difficulty of accurate classification.

TABLE 1

CLASSIFICATION OF THE SAME 50 STUDENTS INTO DIAGNOSTIC CATEGORIES BASED ON READING-ACHIEVEMENT SCORES AND MENTAL GRADE PLACEMENT

Reading achievement test	Classification		
	Nondisabled	Disabled	Severely disabled
GORT[a]	8	7	35
SDRS[b]	15	12	23
GIRI[c]	10	4	36

[a]Gates Oral Reading Test.
[b]Spache Diagnostic Reading Scales.
[c]Georgia Informal Reading Inventory.

When the 50 students were given the Wechsler Intelligence Scale for Children, the Peabody Picture Vocabulary Test, and the Ammons Quick Test, the discrepancies in test scores were considerable as seen in Table 2, even though on the WISC and PPVT the group means and standard deviations were nearly identical.

When the research worker or clinician uses unreliable data from both a reading-achievement test and an intelligence test, he frequently is led to draw invalid conclusions. Because of validity and reliability problems, it is important in the evaluation of research on reading disability to pay special attention to the procedures used in establishing the diagnostic categories.

TABLE 2

FREQUENCY OF IQ POINT DISCREPANCIES FOR PPVT AND QT AS COMPARED TO THE WISC (N = 50)[a]

	WISC		
	Verbal	Performance	Full scale
PPVT higher by:[a]			
1-10 points	15	15	16
11-20 points	12	12	11
21 or more	3	3	3
WISC higher by:[b]			
1-10 points	9	7	10
11-20 points	5	6	7
21 or more	5	7	3
QT higher by:[b]			
1-10 points	7	3	11[d]
11-20 points	13	10	9
21 or more	13	13	13
WISC higher by:[c]			
1-10 points	11	13	6
11-20 points	4	8	9
21 or more	2	3	1

[a]PPVT represents Peabody Picture Vocabulary Test.
[b]QT represents Ammons Quick Test.
[c]WISC represents Wechsler Intelligence Scale for children.
[d]For one pupil, the QT and WISC full-scale IQ scores were identical.

Another problem encountered in making diagnostic classifications is that, too often, the diagnosis of learning disorders is done in a backwards fashion. To establish the existence of a legitimate diagnostic procedure for diagnosing pupils as having a "learning disorder," each member of a large group should be diagnosed by the desired procedure as "having a learning disorder" or "normal" prior to the beginning of reading instruction. All of the children should then be given the same education. At the end of two or three years, the academic proficiency level of each pupil should be ascertained. Unless the pupils originally labeled as having a learning disorder obtain a mean academic proficiency level significantly lower than the mean academic proficiency level of the pupils originally labeled as normal, the diagnostic procedure should be abandoned or drastically revised. In actual practice,

classifications of "learning disorder" or "normal" are done in reverse order. First, a student is noticed as having trouble with reading. Second, he is given a series of neurological tests. These tests frequently have not been standardized in terms of having norms developed and the neurological tests frequently have not been studied for their predictive validity. On the neurological tests the student may show some neurological "soft signs." The combination of reading retardation and neurological "soft signs" is sufficient to classify the student as having a learning disorder. Thus, the diagnosis of "learning disorder" is made after the student shows persistent difficulty in classroom learning.

Testing Nonrelevant Variables

Many studies of reading difficulty investigate variables that have little or no direct connection with the learning to read process. For example, social-class variables, though correlated with reading achievement, are not components of a learning model of reading acquisition. Isom (1968) states that identification of handedness, eyedness, hand-eye correspondence, dominant eye, and writing hand have not served as an adequate basis for classifying individuals by reading level, do not delineate the etiology of reading disability, and do not suggest a basis for remediation.

Matched Group Designs

Another problem encountered with most investigations of reading retardation is that matched-group designs are used. In two important papers, Campbell and Stanley (1963) and Hopkins (1969) point out the pitfalls of matched-group designs. First, it is impossible to match on all the relevant variables. Second, when two groups representing different populations are matched on one variable, regression effects on the dependent variable tend to invalidate the experimental results.

Reed (1970) presents another problem in matching, that is, the selection of the matching variable. In one of his studies he found that when performance IQ was used for matching, the mean verbal IQ of poor readers was 15 points lower than that of good readers. A second problem dealt with the intercorrelations one often finds among tests which measure intellectual functions. Thus, if a battery of tests is used as a dependent variable, and if the tests in the battery intercorrelate, we tend to find a low score on all tests for pupils who have a low score on one test. When Reed matched good and poor readers on full-scale IQ, he found that poor readers did less well than good readers on 7 of the 9 tests. But when he matched his groups on a different variable, a different pattern on the dependent variable emerged. Thus, the results are

a function of how one matches. Select one variable for matching and the poor readers are clearly inferior to the good. Match on a different variable and the poor readers do at least as well as the good readers on the dependent measures.

Determining Cause and Effect

Another problem encountered in research on reading difficulty is that subjects who are failing in reading are selected for study. A history of failure produces effects of its own. For example, reading failure may lead to inattention and desire for escape from situations in which a learning task is presented. Thus, if one observes that poor readers are less attentive than good readers, one cannot be sure whether inattention produced low reading achievement or failure in reading produced inattention.

Piecemeal Studies

Nearly all the studies on causes of reading difficulty investigate single factors. Consequently, we have a large number of studies, each identifying a factor which seems implicated in the problem. What these separate studies cannot do is present a comprehensive picture and weighting of factors which are involved in success and failure in learning to read.

Summary on Shortcomings of Research on Causes of Reading Difficulty

Despite an impressive amount of research on causes of reading retardation, the bulk of the research fails to add up to much: (a) the research has been piecemeal in its approach rather than systematic; (b) the matched-group designs generally used in these studies were inadequate; (c) the students were used for research after they had been identified as having a reading problem rather than before, thus masking what is cause and what is effect; (d) numerous studies have investigated variables which are not components of a learning model of reading acquisition; (e) diagnostic labels were used, which imply that causes of the reading problem were known; and (f) sources of unreliability in achievement-expectancy formulas, reading-achievement tests, and intelligence tests have resulted in invalid research results and conclusions.

REVIEW OF LITERATURE ON COMPONENTS OF ASSOCIATIONAL LEARNING RELEVANT TO READING

In the previous section, one of the criticisms directed at research on the causes of reading disability was

that much of the research was on variables which have little or no direct connection with basic processes involved in learning. What would be desirable would be to have research that focuses upon some of the basic processes involved in verbal learning in order to discover whether differences in verbal learning may not be a function of individual variation in these basic processes. Furthermore, to overcome the problem of piecemeal research, these processes should be investigated in a systematic, comprehensive manner.

Recent conceptualizations within cognitive psychology (Neisser, 1967) suggest what basic processes are involved in verbal learning. These basic processes can be cast within an associational-learning paradigm and studied in this context. Before listing the components of the associational model, it would be useful to trace historically several models of associational learning.

Historical Perspective on Models of Associational Learning

Historically, associational learning was believed to be a simple single-stage process. As psychologists continued to investigate the nature of associational learning, they discovered that S-R learning was anything but a simple, single-stage process. Gibson (1940) detailed the importance of stimulus learning in the associational process. Morikawa (1959) postulated that there were three distinctly different types of learning involved in paired-associate learning: stimulus discrimination, response acquisition, and reinforcement of S-R paired associates. Underwood and Schulz (1960) divided paired-associate learning into a response-learning stage and a hookup stage, in which stimulus and response are joined. McGuire's (1961) model was similar to the Underwood and Schulz model, except for the hookup stage. McGuire postulated a more complicated mediational state. The importance of this mediational state in associational learning has since been documented by the work of Martin, Cox, and Boersma (1965). The recent work of Rohwer (1970), Davidson (1964), and Turnure and Walsh (1970) indicates that S-R hookup is facilitated by psycholinguistic processes such as syntactic elaboration.

The division of associational learning into numerous components has extended beyond three stages. For example, Travers (1967) has stated that in verbal and symbolic learning, the stimulus input stage can be divided into a phase in which information is contained in a pre-perceptual field, a phase in which some of the information from the pre-perceptual field is selected and stored in short-term memory, and a stage in which information in short-term memory is transferred to long-term memory by being associated with previously stored information.

The research literature currently provides evidence for the following processes in associational learning: attention, distinctive-feature learning, visual-recognition memory, mediation and hookup, auditory discrimination, and auditory memory. Obviously, these processes are also involved in learning to read. This testing of factors involved in the associational process indicates how far psychologists have traveled since the early days of thinking of associational learning as a simple, one-stage process.

The proliferation of stages and processes in associational learning has important functions. First, it represents a better understanding of what is involved in associational learning. Second, each separate stage that is identified becomes a focal point for concentrated research in that area. Third, and most important, each of these basic components of associational learning is also involved in the learning-to-read process.

The brief historical review of research on associational learning indicates that psychologists now view this type of learning as being far more complex than originally imagined. Associational learning in terms of the reading task would imply printed verbal-stimulus, verbal-response acquisition. Thus, components of associational learning in reading include: attention, learning distinctive features of visual stimuli, visual-recognition memory, mediational processes, auditory discrimination, and auditory memory.

Attentional Processes

Psychologists consider attention to be so essential to the process of learning that without it there can be no learning. The relationship of attention to learning can be investigated in a number of ways. For example, physiological correlates of attention include changes in the galvanic skin response (GSR), heart rate, blood volume, brain rhythm, and pupillary dilation. Some of these physiological correlates of attention have been demonstrated to be related to learning.

Brackbill (1964) claims that any increase in arousal during learning should also increase retention. Belloni (1964) found that physiological indicators of attention, such as the GSR, were positively associated with learning. In her study, men with high GSR's learned difficult paired-associate lists faster than men with low GSR's.

Farley's (1969) work with kindergarten children using physiological indicators of attention and a paired-associate task indicated a complex sex interaction. High- and low-orienting males did equally well (contrary to Belloni's findings) and surpassed the medium orienters. With females, the

trend was reversed; high and low orienters did less well than those in between. Why there is a sex difference is unexplained, but Farley's work indicates that future work on physiological correlates of attention must deal with males and females separately. What is most intriguing about research on physiological correlates of attention is that there is evidence that individual differences in the orienting response can be used to predict performance in cognitive tasks such as reading. Maltzman and Raskin (1965), for example, have hypothesized that the orienting response is related to discrimination of complex stimuli such as words.

Research on attention has also been concerned with the effects of distraction on learning. Pavlov found that distraction in the form of extraneous noises or the sight of assistants walking about interfered with the conditioning of animals. When Pavlov reduced distraction by placing his animals in enclosed soundproofed cubicles, the animals conditioned more readily. In the performance of a well-learned task, Cason (1938) found distraction made the task more difficult to perform. Deutsch and McArdle (1967) used an auditory test of vigilance and found a positive relationship between vigilance and reading achievement.

Students who are low in academic achievement seem to be more distractible than students who are high in achievement (Baker & Madell, 1965; Silverman, Davids, & Andrews, 1963). Samuels (1967) compared good and poor readers on a reading task when distracting pictures were present. He found that poor readers were distracted by the pictures and learned less than the good readers. In one of the best studies on reading disability, Brewer (1967) found small differences between dyslexic readers and their matched controls in some paired-associate tasks. He thought this difference might have been the result of low motivation or inattention.

The work of Turnure (1969) casts doubt upon some common notions regarding age trends in ability to inhibit attention to nontask relevant distracting stimuli. His data indicate that some distracting stimuli are so salient that older children are as distracted as young children. Under some distracting conditions, his subjects out-performed subjects in a nondistracting condition.

Zeaman and House (1967) have put forth an extremely interesting explanation of one of the reasons why there are differences in learning ability between retardates and normals. They have evidence indicating that for some learning tasks the retardate does not know where to focus attention during early learning trials. Once the retardate discovers the relevant dimension, his learning curve is similar to the normal's.

Where the learner focuses attention, what cues he selects, and whether focal attention is directed at a relevant dimension of the stimulus complex have important implications for reading. Reading educators must decide if their objective is to foster rapid initial learning at the expense of transfer. For example, Samuels and Jeffrey (1966) found that if beginning readers were given words to learn to read by the whole-word method that were highly discriminable from each other, learning was rapid because incidental cues such as first letter or last letter only were used. At transfer, when different words having the same first or last letter were presented, students tended to mistake them for words on the original list. We can infer from this that reading methods which begin with the whole-word approach and use words that are easily discriminated from each other will produce rapid initial learning followed by confusion. Classroom teachers report rapid learning of a small sight vocabulary followed by a plateau. The plateau probably represents that point at which the student finds that his use of irrelevant cues (e.g., single letters, length) can no longer produce the correct verbal response. Further progress in word recognition must wait until he learns more appropriate strategies for decoding.

If words are printed in color, the learner may focus attention on the color and not the letter shape (Samuels, 1968, 1970b). Although rate of learning the word in color may be impressively rapid, when the incidental color cue is removed and what is left is the letter printed in black, the response is lost. Again we find rapid learning at the expense of transfer. Design of curricular materials and methods in reading must consider problems of focal attention and transfer.

The final study in this section is, perhaps, the most relevant. Lahaderne (1968) found a significant correlation between attention and reading achievement in a fifth-grade class. Although intelligence was also correlated with both reading and attention, after its influence was partialed out, a significant relationship between attention and reading was still found. One cannot infer causality of the relationship from this, however, since it is possible that poor reading led to inattentive behaviors.

Summary of Literature on Attention

The literature indicates that physiological correlates of attention are related to learning, that students who are low in achievement tend also to be more distractible than students who are high in achievement, and that at the upper elementary level, a positive relationship exists between attention and achievement. There is also evidence that whole-word methods of teaching reading in combination with highly discriminable words and the use of incidental cues such as color

coding words can lead to rapid initial learning but poor transfer.

The literature reveals an important gap; namely, no one has investigated individual differences in attention and distractibility in a first-grade class and related this to measures of reading achievement. If a positive relationship is found, a follow-up study might select those students early in first grade who show indications of inattention and use precision teaching techniques to determine the effects on reading achievement in this select sample.

Learning Distinctive Features of Visual Stimuli

The ability to discriminate letters and words visually is essential in learning to read. Some authorities on reading difficulty, such as Benton (1962) and Frostig (1961), believe that one of the more important causes of reading difficulty is poor form discrimination. Partial support for this point of view was offered by Goins (1958) who found a relationship between speed of visual perception and reading ability. However, since she did not control for IQ, her conclusions may be invalid.

Busby and Hurd (1968) suggest that where a relationship between visual perception and reading is found, it may be an artifact of how the data were analyzed. When positive relationships are found, it is usually between the extremes, i.e., the best and worst in perception. Busby and Hurd analyzed their entire sample, not just the extremes, and found no relationship. Again, it is important to note, the stimuli used in their tests have no relationship to the type of discrimination required in discriminating letters. Perhaps, if the discrimination task were more relevant to reading, their results might be different. Nevertheless, their admonition about data analysis deserves consideration.

Another study finding differences in form discrimination between poor and good readers is reported by Spring (1969). He matched dyslexic and normal readers on age, IQ, sex, and school to determine whether dyslexics process visually presented uppercase letters more slowly than normals in a same-different reaction-time study. He found latencies were longer for dyslexics than for normals. However, a cautionary note should be added. If the normals had mastered the distinctive features of the letters whereas the dyslexics had not, one would expect a difference in latency due to prior learning. A more convincing study might have used the Gibson figures and their transformations. By using these letter-like forms, both groups would have had equal unfamiliarity with the stimuli.

One approach to the study of visual perception and reading has been to determine if there are gross perceptual differences between good and poor readers. Bonsall and Dornbush (1969) compared good and poor readers on the ability to note whether two stimuli were alike or different in grades 2, 4, and 6. The stimuli were pseudo words like "cuin" and "ciun." No difference between good and poor readers was found in ability to make these discriminations. Critchley (1964) and Vernon (1957) also found no evidence that tests of form discrimination differentiate good and poor readers.

The Frostig technique, which trains on form discrimination, has been investigated in a number of studies. Olson (1966) gave 121 third-graders tests of reading achievement and the Frostig Developmental Tests of Visual Perception. Correlations between the reading achievement measures and the Frostig tests tended to be low and nonspecific to reading. Similar results were found by Goldmark (1964). Rosen (1965) randomly assigned 12 first-grade classes to a Frostig visual-perception training program and 13 classes to a control group. He found that the experimental classes did improve in visual perception skills, as measured by Frostig tests, but were no better than the control classes in reading achievement.

Another test of the Frostig program was done by Buckland (1969). First-grade children were given visual training with stimuli taken from the Frostig materials. These materials do not require the kinds of discriminations which must be made with letters and words. Buckland found no difference in word recognition between the group getting visual training with the Frostig materials and the control group.

Money (1962) has stated that ocular and optical defects are of negligible significance in reading retardation, but to learn to read, the child must learn the features of letters that distinguish one from the other. Krise (1952) concluded from her study of reversals in reading that children with reading difficulty need remedial work centered on features of letters which distinguish one from the other. Monroe (1932) also recognized that children with reading difficulties tended to confuse similar letters. This would imply that poor readers have difficulty noting the distinctive features of roman letters.

In order to determine what the distinctive features of uppercase letters are, Gibson et al. (1963) presented capital letters to four-year-old children. Their task was to select a letter from among several which matched a standard. An analysis of the mistakes indicated that the children tended to confuse letters that shared similar distinctive features. Thus, the letter "O" tended to be confused with "G," "Q," and "U." From these mistakes a confusion matrix was constructed indicating which letters share distinctive features. Popp (1964)

did similar work with lowercase letters. Fibson, Schapiro, and Yonas (1968) used same-different reaction times to letter-pairs and were able to diagram the feature similarities of uppercase letters.

Several studies show the transfer effects of distinctive feature training. Jeffrey (1958) and Hendrickson and Muehl (1962) had children make a left motor response to "b." Children who had this motor-response training were superior to their controls in learning to name these letters. These results were interpreted to indicate the importance of motor responses as a mediational factor in associational learning. Today, these same results would be interpreted to mean that attention was focused on the relevant dimension of difference between the letters.

Pick (1965) found that if kindergarten children noted distinctive features of letter-like forms, they made fewer discrimination errors than a control on a transfer task containing stimuli which were dissimilar in appearance but which contained the same distinctive features as found in the training forms. Pick, Pick, and Thomas (1966) found that distinctive-feature training in one sense modality transferred to other sense modalities (e.g., from touch to vision). The implication of this finding to training on letter discrimination is that prior training in noting distinctive features of letters through the sense of touch via blocks, raised letters, etc., should transfer to visual-discrimination learning. Whether this sequence of training is the most efficient if time is the criterion or whether it is most effective with certain types of learners bears investigation. Although distinctive feature learning was found when simultaneous discriminations were required, Pick (1965) found that schemata learning also resulted under conditions of successive discriminations where memory was required. The author concludes that under conditions of successive comparison, schema learning occurs; but when no memory is involved, schema learning does not occur.

Samuels (1969) found delayed matching-to-sample distinctive-feature training, which required memory, resulted in superior letter-name learning in comparison to a group which did not have to rely on memory during training. Williams and Ackerman (1968) also found that a training task requiring discriminations from memory resulted in reliably better learning on high-similarity trigrams. Similarly, Williams (1969) found that kindergarten children trained to discriminate distinctive features visually in such a way that memory was required were superior in a test of discrimination skill to a group getting reproduction training on the same figures.

The last study demonstrating transfer to distinctive-feature training (Samuels, 1970a) is one in which kindergarteners were trained to note distinctive features of "b," "d,"

"p," and "q," and were then trained to name the letters. The group which received distinctive-feature training prior to instructions on hooking up the letter-name with its symbol experienced fewer failures to learn and learned faster than the group getting discrimination training on the same letters but not on their distinctive features.

Summary of Literature on Distinctive-Feature Learning

Belief that poor readers have difficulty in form discrimination has received some empirical support, but those studies reported here have failed to control either intelligence or prior learning. A number of investigators failed to detect any difference in form discrimination between good and poor readers. Where failure to find differences between good and poor readers are reported, one must determine whether the visual tests use stimuli that are so grossly different that the discriminations are too simple, and more to the point, whether the discriminations are at all relevant to letter and word discrimination. Correlations between tests of visual perception on the Frostig materials and word recognition are low and training on the Frostig materials does not seem to facilitate reading acquisition.

A most promising research domain has been on distinctive-feature learning and training. Distinctive-feature training in one sense modality transfers to another, suggesting that consideration be given to the advisability of giving children early touch training on distinctive features of roman letters prior to visual training as well as using touch training on distinctive features for particular problems poor readers may have.

There is also suggestive evidence that simultaneous discrimination training as contrasted with successive, which depends on memory, produces somewhat different results. Whereas simultaneous presentations lead primarily to distinctive-feature learning, successive discriminations lead to schema and distinctive-feature learning. Successive-discrimination training seems particularly advantageous with highly similar stimuli.

Finally, learning letter names is facilitated considerably and failure in this task is sizably reduced by giving prior training on noting distinctive features of letters before instruction is given in associating the letter name with its printed symbol.

Visual and Auditory Memory

During the process of associational learning, memory for previously presented visual and auditory stimuli is required.

In explaining human memory, psychologists (Atkinson & Shiffrin, 1968; Neisser, 1967; Norman, 1969) have developed models that contain three components. These components are visual-information store (VIS), short-term memory (STM), and long-term memory (LTM). The effective life of information in VIS is about one second (Averbach and Sperling, 1961; Sperling, 1960). Information in STM survives for about 15 seconds if it is not recoded or rehearsed (Waugh & Norman, 1968). Information in LTM survives for an extended period of time.

When a stimulus is flashed, it is placed in VIS and stored briefly on the retina as an after-image (Sperling, 1960), somewhat like an image on a photographic print. However, the difference between VIS and a photographic print is that VIS decays in about one second. While it is agreed that there is simultaneous storage of the stimuli on the retina, there is conflicting evidence whether the briefly stored image is processed simultaneously or serially (Bamber, 1969). If a second stimulus is flashed prior to processing the first image in VIS, the first image can be erased. The implication for reading is that one function of the fixation pause is to prevent new stimuli from interfering with the processing of the image in VIS (Gilbert, 1959).

Just as there is rapid decay of information in VIS, there is evidence (Eriksen & Johnson, 1964; Guttman & Julesz, 1963) that unattended auditory stimuli decay steadily from zero seconds on. Thus, both visual and auditory stimuli undergo rapid loss unless they are processed. In the Peterson and Peterson (1959) procedure, where rehearsal is prevented, accuracy of recall declines rapidly within a period of 0-15 seconds. One way to reduce loss of auditory information is through rehearsal, but how can one "rehearse" a visual stimulus?

Bartlett's (1932) work on memory provides some clues as to how visual memory is stored. Bartlett presented a picture of an animal that resembled a cross between an owl and a cat. He then had his subjects draw the object from memory. At times, the drawings resembled cats; at other times, they resembled owls. Apparently, the visual image is encoded verbally as either "cat" or "owl." Depending on how the original image is recoded, the reproduced drawing resembles the encoded verbal description.

Additional evidence as to the fate of visually presented stimuli is presented by Conrad (1964), Sperling (1963),

and Steinheiser (1970). In all cases, visual stimuli were presented (e.g., letters) and reports were solicited. In numerous cases, the errors were due to auditory confusions, or to verbal substitutions or to errors in manner and place of vocal articulation, suggesting that the visual stimuli were encoded verbally. Thus, it seems as though visual information is recoded as a verbal surrogate. According to Conrad (1964), the information stored in STM is auditory in form.

Visual information in VIS and auditory information in STM are both rapidly lost. To reduce this loss, the VIS is recoded auditorily. Obviously, the accuracy of the verbal description will affect the accuracy of the memory. However, to prevent loss of verbal information, rehearsal must take place, this rehearsal being in the form of sub-vocal repetition of a verbally encoded item.

According to Brown (1958), short-term forgetting is due to decay of the memory trace. The function of rehearsal may be to prevent decay or to establish a new trace. However, according to Waugh and Norman (1968) the function of rehearsal is to prevent new information from interfering with the short-term retention. Thus, the two explanations for loss of information from STM are decay and interference.

Although visual stimuli can be encoded verbally, there is suggestive evidence that visually presented stimuli do not necessarily have to be encoded verbally in order to be stored (Kaplan, Yonas, & Shurcliff, 1966; Posner, 1966). Haber (1964) reported that about 8 percent of elementary-school subjects had eidetic images which lasted at least 40 seconds. These subjects, when reporting their images, appeared to be scanning as they reported fine detail. The images were positively colored. Doob (1964, 1965) also reported eidetic imagery among adult African Ibos. It seems that eidetic imagery in Western culture is lost at maturity due to acculturation.

If all visual stimuli had to be encoded verbally for memory storage in the human, it would be difficult to explain visual-recognition memory in the infant prior to his acquisition of a functional language. It may be that visual information is stored as an image prior to the development of a functional language. With the onset of language, visual stimuli are encoded verbally. In addition, phenomenological evidence from animals, where language is absent, indicates that they have visual memory in the absence of language. Furthermore, humans do have vividly colored images in their dreams, and they occasionally have images when awake. Penfield (1952, 1954, 1958), who excited portions of the brain with electrodes, said his patients were startled by vividly clear images, either visual or auditory. Such evidence suggests that a model of human memory should include visually stored images.

The manner in which visual stimuli are processed during discrimination learning affects what is learned. Pick (1965) found that if simultaneous matching-to-sample training was given, distinctive-feature learning occurred, but if succession matching-to-sample training was given, both schema and distinctive-feature learning occurred. Samuels (1969) also found superior visual-recognition memory for stimuli that had been discriminated under successive matching-to-sample.

Among those who have written about reading difficulty (Benton, 1962; Rabinovitch, 1962), there is a strong belief that impaired visual memory is implicated. However, until recently, there were few data to support this point of view. Good and poor readers, matched on IQ, were presented lines, letters, and word configurations (Lyle & Goyen, 1968). Subjects had to identify the same form in a multiple-choice test under conditions of immediate and delayed recall. The fact that poor readers did less well under both conditions implied that poor visual memory is associated with poor reading.

A promising technique for the study of recognition memory was used by Shephard and Teghtsoonian (1961). Subjects are first presented a number of stimuli. Then a test is given during which either the same stimuli previously seen or new ones are presented. During the test, the subject must say "old" if he has seen the stimulus before or "new," if he has not. In addition, he must give a confidence estimate of how sure he is of his test answer.

Using the technique just described, Bernbach (1967) investigated the relationship between visual-recognition memory and paired-associate learning. His hypothesis that S-R association depended on visual memory of the S-term was supported. Similarly, Martin (1967) found in an auditory-auditory paired-associate task that auditory memory was an essential factor in associational learning. The model of paired-associate learning developed by Underwood and Schulz (1960) presupposes R-term memory as an essential prerequisite to S-R hookup.

Anderson and Samuels (1970) found in a randomly selected sample of third-graders that visual memory, though not significantly correlated with IQ, was significantly correlated with paired-associate learning and reading achievement. Their data suggested that the superiority of the good readers was due to their ability to encode consistently the distinctive features of the visual stimuli. Poor readers either had difficulty in attending to or identifying the distinctive features of stimuli. It seems that visual memory is influenced by ability to identify distinctive features and encode them with an accurate verbal label.

Summary of Literature on Visual and Auditory Memory

Models of human memory have included three components, two of which may be considered hypothetical constructs. The three components are visual-information store (VIS), short-term memory (STM), and long-term memory (LTM). Visual information is stored briefly on the retina and decays in about one second. New visual stimuli presented while the first stimulus is in VIS can interfere with processing the first stimulus. It is believed that the function of the fixation pause in reading is to prevent new stimulation from interfering with the word-recognition process. Visual and auditory stimuli are lost rapidly if rehearsal is prevented. Current explanations of information loss in short-term memory involve decay of memory trace and interference from new information. The function of rehearsal, then, according to each of the explanations, is to prevent decay or to prevent new stimulation from interfering with old.

Since the visual information in VIS decays so rapidly, how is it stored? There is good evidence that visual information is encoded verbally and placed in short-term memory where it may survive for up to 15 seconds. However, there is suggestive evidence that visual information may be stored as a visual image. If all visual information had to be recoded verbally to be stored, it would be difficult to explain visual memory in humans prior to onset of functional language or visual memory in animals.

Research on visual memory and reading indicates that poor reading is associated with inferior visual memory. The superior visual memory of the good reader appears to be due to his ability to identify distinctive features and to encode them verbally with accuracy and consistency. Improvement in visual memory may result from helping the learner to discriminate and to encode the distinctive features of visually presented stimuli.

Auditory Discrimination

There are few areas in psychology which present as tangled a web, as many conflicting points of view and conflicting evidence, or as much naiveté in the research as in the relationship of auditory discrimination to reading. Before reviewing the research and presenting various points of view, it might be timely to state briefly how auditory discrimination has been measured:

1. When given pairs of words, the subject must indicate if they are the same or different. E.g., tat-dat, salt-sought, jaw-jar.

2. When given a sound, the subject must name a letter that contains the sound. E.g., /s/--letter "s."
3. Given components of a word, the subject must blend them to reform the word. E.g., /c/-/a/-/t/-"cat."
4. Given a sound in a word, the subject must locate a picture whose name has the sound indicated. E.g., The child is given a picture of a door, a garden, and a gate. The examiner says, "Listen, when Gus started to school, he forgot to shut something. What Gus forgot to shut begins with the first sound in his name. Draw a line under the picture of what Gus forgot to shut."

Recent research that focuses on the methodology of testing auditory discrimination strongly suggests that task variables that were not controlled and procedural shortcomings may have invalidated many of the studies on discrimination and reading. For example, when kindergarten and first-graders were given tests of phonological discrimination that lasted several days, performance on the first day was significantly worse than on the other days (Rudegeair & Kamil, 1970). The authors said that repeated testing is a must for young children. Since most auditory-discrimination tests are given but once to untrained students who may fail to understand the instructions, there is an excellent chance that the test results are unreliable.

Another criticism of discrimination tests (Templin, 1957, p. 61) is that some of the test items appear to be tests of intelligence. For example, among the four statements listed above of how auditory discrimination is measured, type 4 appears to require more than simple auditory discrimination. In addition, there is some doubt that children comprehend the task instructions. For example, children may have difficulty making same-different judgments without prior training. Even well into grade one, Meltzer and Herse (1969) found that 82 percent of the children could not identify a word in written or spoken form. How children can respond appropriately on an auditory-discrimination test with concept deficits such as this is difficult to understand.

While some reading authorities have concerned themselves with relationship between auditory discrimination and reading achievement, claiming that the ability to hear the separate sounds in words is important in learning to read (Durrell, 1940; Harrington & Durrell, 1955; Wepman, 1960), others have concerned themselves with the problem of phonological deviations and auditory-discrimination abilities of dialectally different speakers. The concern is that the mismatch between one's dialect and the dialect of written and spoken instructions is a cause of interference in learning. Since the term "dialect difference" is seldom precisely defined in the literature, it is frequently difficult to

determine whether the author is referring to phonological, syntactical, or semantic differences. Among those who believe that dialect differences from standard English lead to reading problems are Stewart (1969), Labov (1969), and Baratz (1969). Labov (1969) has stated that ignorance of standard English by nonstandard English speakers and ignorance of nonstandard English by teachers contributes to problems in reading.

Prescriptions for overcoming reading problems stemming from dialect differences include: giving the child structured lessons in language which will prepare him for the school situation as well as having primers written in the child's own dialect (Modiano, 1968; UNESCO, 1953).

Contrary to those who believe auditory-discrimination deficits and dialect differences are associated with reading problems, there are those who believe the link is tenuous, at best. Weiner (1967, p. 19), for example, states that results of studies on auditory discrimination are conflicting and inconclusive. The weight of evidence is against there being a systematic inferiority to discriminate speech sounds in reading defectives. Weber (1969) has also expressed doubt that dialect differences are a cause of reading difficulty. In a penetrating criticism of methods used to teach reading to special populations, Venezky (1970) has pointed out that nonstandard dialect speakers may be deficient in attention and cognitive development, and these factors, not dialect differences, may be the underlying factors in reading difficulty. Savin (1971) believes that an important skill deficit in poor reading may prove to be difficulty in sound synthesis (e.g., /f/+/a/+/t/--/fat/) and sound analysis (e.g., /fat/ minus /f/ is /at/). An instructional program designed to teach sound analysis and synthesis that transfers to reading has been reported by Rosner (1971).

In the formulation of Bernstein (1960) and Deutsch (1964), restricted language codes and dialect differences are thought to underlie the problem of academic underachievement in minority and lower-class groups. Baratz (1969) and Wardhaugh (1969) have attacked the view that the linguistic differences of certain groups from norms of standard English imply inferiority. They contend that nonstandard Black English, for example, is a well ordered, highly structured, highly developed language system. The tests used to measure auditory discrimination are based on standard English. In comparison studies, lower-class Blacks of nonstandard speech are compared with middle-class whites of standard speech. When differences do show up in reading, they are attributed to the linguistic differences when they could be attributed to other factors as well.

It seems clear that if one uses auditory discrimination tests which are keyed to standard English, so called

"deficiencies" will appear in economically disadvantaged populations (Clark & Richards, 1966). Deutsch (1964) attributed the fact that Blacks from disadvantaged homes did not discriminate speech sounds as well as Whites from the middle class to a noisy environment. Baratz (1969) has rejected this explanation, stating that the discrimination tests require Blacks to make distinctions which they do not make in their own dialect. For example, when Blacks are given word pairs to discriminate which are homonyms in Black-English dialect but which are different in standard-English dialect, obviously the Blacks will not do as well as the whites.

To counter the belief that some environments are more conducive to language development, Lenneberg (1964) has compiled impressive evidence indicating that speech development--like walking--is a maturationally determined behavior, and with the exception of what language we learn to speak, is uniquely free of environmental influence. He finds that children from all parts of the world go through the same stages of language development at the same period in their lives. Whether one wears shoes to school or sandals and whether one discriminates /told/ from /toll/ as in standard English or hears both as homonyms as in Black-English phonology, are culturally determined and are of trivial consequence from a developmental-linguistic viewpoint.

Some writers attribute the fact that nonstandard speakers of English generally do less well in reading to their lower scores on auditory discrimination tests and the mismatch between their language and the language used in reading textbooks. Weber (1969) submits that the "Oh, look; oh, look" style, the "Nan, can, fan, Dan" style, and "Faster went the train" are written in a dialect that is strange to all children. Furthermore, as Weener (1969) and Mitchell-Kernan (1969) have demonstrated, the lower-class speaker is capable of comprehending speech in two dialects, his own and his teachers'. It is generally the middle-class person who has difficulty in switching styles and in comprehending lower-class speech. Finally, in rapidly spoken standard-English speech, many words that are spelled differently are pronounced the same. In saying "He told me," the "d" in told is not pronounced. Thus, "toll" and "told" sound similar. The comprehension problem is not great since context provides powerful cues. It is only on auditory-discrimination tests, where minimally contrasting word-pairs are pronounced in isolation that discrimination of all elements is so critical.

When Melmed (1970) compared third-grade Black English and standard-English speakers on a test of auditory discrimination in which words are spoken in isolation, he found Blacks to be less able to discriminate word-pairs (e.g., toe-tore, jar-jaw) that are homonyms in their speech. But when these same words were spoken in context, they had no difficulty

in discriminating between them. Moreover, on a test of reading comprehension, there was no difference between the groups.

Despite evidence, which will be presented shortly, that auditory discrimination deficits are related to reading, not all researchers have found this to be so, nor have some been impressed with what they found. For example, when a group of poor readers was divided into levels based on their auditory-discrimination errors, no relationship was found between reading and discrimination errors (Poling, 1953). After an extensive investigation of the relationship between auditory discrimination and reading achievement, Dykstra (1962) found relatively low correlations (under .43) between discrimination and word recognition. He concluded that developing the auditory discrimination of pupils will not be sufficient to insure their learning to read. Wheeler and Wheeler (1954) also found correlations between auditory discrimination and reading in the same range as Dykstra and concluded that at the intermediate grade level there was no reason to believe a substantial relationship existed between discrimination and reading.

Reynolds (1953) gave elementary students tests for blending and word-pair discrimination. Although he found blending ability not highly related to reading (r = .10 to .40), he found word-pair discrimination to be more closely related to reading level. However, when MA was partialed out, the correlations were not significant. He concluded that none of the measures of auditory discrimination adds significantly to MA for purposes of prediction.

In order to test the assumption that the mismatch between Black-English dialect and the language of the classroom is a cause of reading difficulty, Rystrom (1970) gave 25-minute daily lessons for 8 weeks on standard English. He found no relationship between dialect training and reading achievement. In a redesigned study, Rystrom (1970) again found no improvement. In fact, in comparison to a control, dialect training had a significantly negative effect on decoding skills. Furthermore, the dialect training did not affect ability to produce phonologically proper utterances.

Despite the negative findings and the low correlations between auditory discrimination and reading, a substantial number of people believe that auditory discrimination is an important factor in reading. Bond (1935) matched 64 pairs of good and poor readers on sex and IQ in grades 2 and 3. He found differences in auditory discrimination between the reading groups. However, some of his tests required giving letters for sounds, which is a reading skill as well as a discrimination skill. Both Monroe (1932) and Wolfe (1941) found poor readers inferior in auditory discrimination to average readers. Gates (1940) tested 173 children and reported a

correlation of .28 between rhyming and reading achievement. Schonell (1948) and Robinson (1946) report discrimination difficulties associated with poor reading. Templin (1957) tested 318 children and found correlations ranging from .22 to .47 between tests of auditory discrimination and reading. Harrington and Durrell (1955) tested 500 second-graders in Boston. The children were divided into good and poor readers and matched on MA, visual discrimination, and phonics ability. They found highly significant differences between good and poor readers in auditory discrimination. Wepman (1960) found a high correlation between discrimination and reading, but there is no evidence for control of SES or race. Finally, Goetzinger, Dirks, and Baer (1955) matched 15 pair of good and poor readers on sex, age, IQ, and visual acuity. They found a correlation of .56 between word-pair discrimination and reading.

Summary of Literature on Auditory Discrimination

Few areas in psychology present a more perplexing picture with conflicting viewpoints than the area of auditory discrimination. Concern for auditory discrimination and reading began with the belief that decoding ability required the ability to hear the separate sounds in spoken words. Present concern is expressed by the belief that mismatch between nonstandard English of the home and the standard English in the schools produces reading problems.

Recent criticism of methods of testing discrimination as well as the tests themselves leads one to take a stance of caution with regard to claims that discrimination problems are important factors in reading underachievement or that dialect mismatch produces interference in learning. Recent work on phonological testing lasting several days shows significantly worse scores on the first day, leading these researchers to warn that repeated testing is essential if one is working with children. The requirements of making same-different judgments about minimally contrasting word pairs is beyond the performance level of many children. In fact, many first-graders well into the reading process still do not know what a "word" is in visual or auditory form.

A criticism of the discriminative tests themselves is that they establish a norm of middle-class standard English for all speakers. When nonstandard English speakers fail to hear sounds, it has been attributed to linguistic underdevelopment or to noise in the environment. To the contrary, the linguists claim the particular sounds not discriminated are simply sounds which do not function as phonemes in the speaker's environment.

New insights into biological and nativistic foundations of language place discrimination differences in the

realm of cultural variability rather than a deciding cause of reading difficulty. Since in many dialectally different groups there may be differences in attention in school settings, motivation, and cognition, one is hard pressed to understand why auditory discrimination rather than some other factor is selected as the cause of reading difficulty.

The assumption is made that the mismatch between dialect and printed English is a cause of reading difficulty. Actually, all children find the language of the reading textbook to be strange. Recent investigations of auditory discrimination indicate that when minimally contrasting word pairs are presented in isolation, the economically disadvantaged child does indeed do less well on a test of auditory discrimination. But when the critical word is embedded in a sentence, he comprehends it in speech or writing as well as his more advantaged counterpart. Furthermore, lower-class children seem able to comprehend both lower- and middle-class speech. It is the member of the middle class who cannot code switch, showing ability to comprehend only middle-class speech. Perhaps, it is the middle-class teacher, not the lower-class child who needs special instruction. The teacher may require training in accepting the dialect differences of her pupils. Attempts to modify the dialects of nonstandard speakers and to improve their reading indirectly thereby have ended in failure on every count. Considering the several areas where intervention can produce changes, areas such as attention, visual distinctive future learning, and memory, the area of auditory discrimination does not seem to be particularly promising.

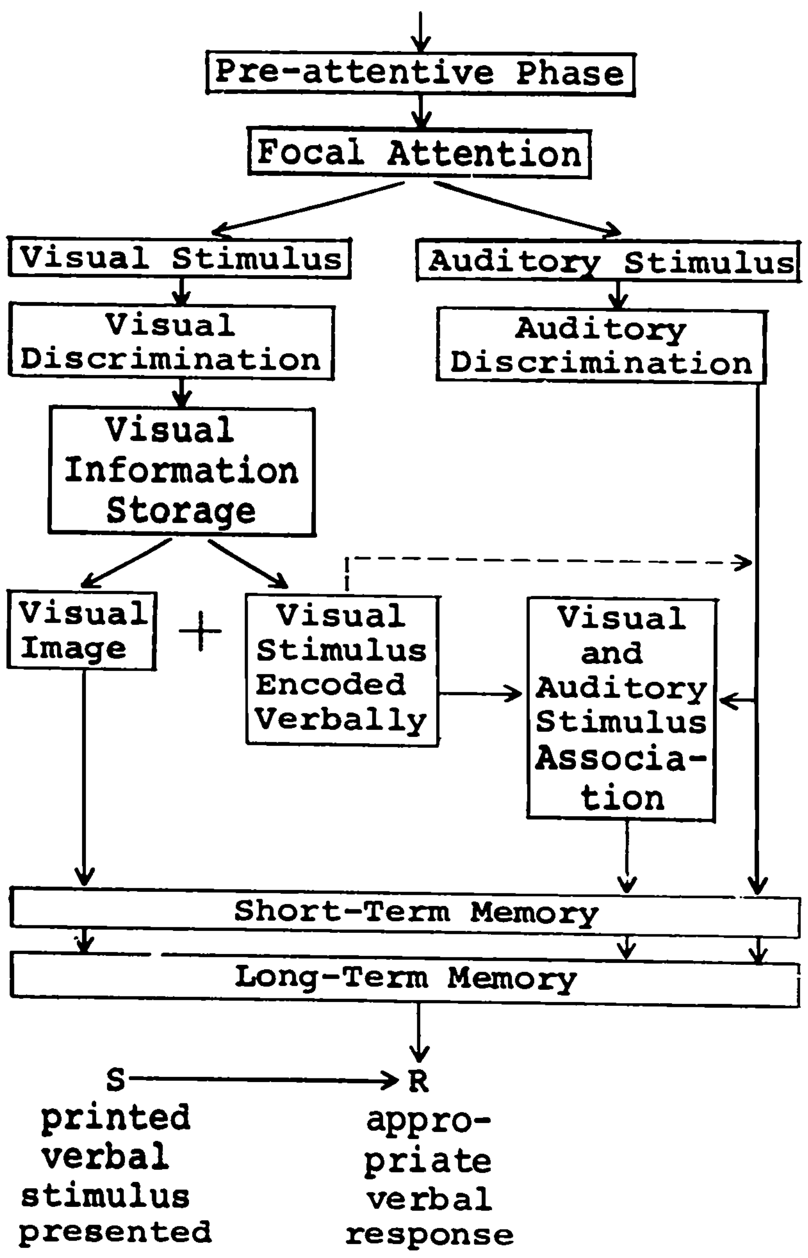
RESEARCH STRATEGY FOR STUDYING FACTORS ASSOCIATED WITH DIFFERENCES IN READING ACHIEVEMENT

Introduction

The purpose of this section will be to present a method for studying variables associated with differences in reading achievement that overcomes the criticisms of research on this topic detailed earlier. As part of the method for studying reading difficulty and success, a model of associational learning is set forth, the components of which are considered to be basic to the verbal-learning process.

In the first section of this article, the criticisms which were directed at research on factors differentiating good and poor readers included: comparing good and poor readers on variables which had no direct connection with the learning process, using matched-group designs, unreliability of prediction formulas, reading-achievement and IQ tests, piecemeal research, and using students with a history of reading failure.

MODEL OF ASSOCIATIONAL LEARNING



Research on components of associational learning related to reading achievement	Research on improving reading achievement
Role of attention in beginning reading has not been investigated. The extent to which distinctive-feature learning distinguishes good and poor readers is unknown. The extent to which reading achievement is related to auditory-discrimination ability is unknown. What is the relationship between visual and auditory memory and reading achievement? Are mediational strategies and speed of S-R hookup related to reading achievement?	Will the use of precision teaching and behavior-management techniques increase reading achievements? What methods improve distinctive feature learning? What kinds of distinctive feature learning and auditory-discrimination learning lead to increased reading achievement? What methods lead to improved visual and auditory memory? Will application of methods which improve visual and auditory memory increase reading achievement? Will training on mediational strategies and imagery techniques facilitate the hookup phase, and does this training transfer to improved reading achievement?

If we are to gain a better understanding of the factors associated with success and failure in reading, we must overcome the criticisms just mentioned. Despite the interest among researchers in finding out why children have difficulty learning to read, there are those who claim that learning why the difficulty exists will not solve the problem. Instead, they suggest concentrating on aspects of the instructional process which will facilitate the learning process. For example, if lack of motivation or inattention is a problem, they recommend training the teacher in precision teaching. If failure to learn distinctive features of letters is a problem, develop an instructional method which will teach the distinctive features. To accomplish the somewhat different goals of determining why children fail as well as developing ways to help them, two research strategies are presented with the model of associational learning. However, the emphasis here is not on designs for testing instructional methods.

The emphasis in this paper given to the design of research on factors associated with success and failure in reading is not because this topic is thought to be more important than research on improving the learning process. The design of experimental research on facilitating reading, in which cause-and-effect relationships can be pinpointed, is straightforward in its methodology. The emphasis in this paper given to the design of research on factors associated with what appears to be reading difficulty grows out of continued interest in this topic on the part of researchers and the need for new ways to study the problem.

In order to overcome the shortcomings which can be found in many studies on reading difficulty, the research should focus on variables considered to be basic components of the learning process and these variables should be studied in a comprehensive rather than a piecemeal fashion. One way to decide what variables are basic is to start with a model of the associational learning process. As seen in the model of associational learning, there are several components in associational learning. This model draws heavily upon conceptualizations from cognitive psychology. Once again the reader is cautioned against interpreting this model as one which represents reading.

Components of the model of associational learning consist of attention, visual and auditory discrimination, short- and long-term memory, and mediation. Since many of these components have been described in the previous section, these components will be described only briefly in terms of their functioning within the model.

Attention

Attention can be considered to be the allocation of energy and analyzing mechanisms. This allocation of analyzing mechanisms is manifest by head and eye movements as well as by other sensory mechanisms so as to emphasize certain stimuli at the expense of others. Attention is not directed at random over the broad surface of a field. Instead, it is directed at a region within a field. Since attention has limited capacity for processing incoming stimuli, the purpose of allocating attention to a limited region within a broader field is to maximize the probability that certain stimuli are received and processed.

In terms of a learning-to-read situation, attention on the part of the student entails a broad class of behaviors which the classroom teacher views as "cooperation" or "good deportment." If the teacher's instructions are to "look in the book" or "listen" or "do reading-related seatwork," the student complies. The student looks and listens as directed. If the student cooperates and engages in these manifestations of gross attention, the teacher is satisfied. There is evidence that these behaviors are positively correlated with reading achievement. In addition, it is these cooperative behaviors of complying with her instructions which is what the teacher means when she indicates the student is attentive.

When the student is attentive, he is alert to signals which direct his attention to a region. When the teacher says, "Look at the board and find out how 'b' and 'd' are different," the student hears the teacher and locates the graphemes. Thus, the learner's attention is directed at the source of a signal (the teacher's voice, which is a limited region in the broader field) followed by a shift in attention to the region directed by the teacher.

Ordinarily in the learning-to-read situation, when associational learning is required, two sources of stimuli are presented to the learner, as seen in the model. A printed visual stimulus is presented. It could be a single letter, a word, a phrase, or a sentence. In addition, there is an auditory stimulus, consisting of the auditory counterpart of the letter, word, phrase, or sentence. Hence, there are two sources of stimuli presented to the learner, one in visual form and the other in auditory form. The learner's task is to associate the two. When associational learning is completed, the learner should be able to give the appropriate verbal response to the printed stimulus.

Visual Discrimination

Since to the young learner, many roman letters seem to be so highly similar in appearance (e.g., b, d, p, q, h,

u, v, n), his first task is visually to discriminate them from each other. Obviously, also, many words in English bear striking similarities to each other (was, saw; show, slow; bad, dab). These, also, require exact discrimination.

There are several levels of learning involved in visual discrimination. At one level, there is accuracy in discrimination, but speed is slow. The second and desirable level is feature discrimination and recognition at the automatic level. At the automatic level, discrimination sinks below the threshold of attention.

In order to identify letters reliably and quickly, for example, it is necessary to learn their distinctive features. Whereas at first noticing the distinctive features may require considerable search time, at the automatic level, feature processing and identification is rapid and automatic.

There is evidence that one may learn and store in memory not only distinctive features but schemata as well. Whether one learns distinctive features or schemata, or both, depends upon whether simultaneous or successive discrimination training, or both, were given.

Visual Memory

The function of visual memory is to enable the learner to recognize a visual stimulus that has previously been seen. Without this ability, it would be impossible for the learner to profit from prior experience and learning.

As mentioned in the literature review, visual information placed in Visual Information Store has an effective life span of less than a second. To prevent its permanent loss, it is encoded verbally. In terms of distinctive features, it may mean encoding the "b"-"d" difference as "ball to the bottom right" or "ball to the bottom left." The verbally encoded information thus becomes part of short-term memory. Short-term memory appears to be primarily auditory.

Usually, in the learning-to-read process, the visual stimulus remains exposed for a period of time long enough so that loss of visual sensation from Visual Information Store is not the serious problem it is with briefly exposed stimuli. Nevertheless, there is the need to recognize previously seen and processed stimuli. This identification and recognition of a visual stimulus does seem to entail retrieval of verbally coded material. In addition, visual memory probably also entails retrieval of visually stored images or schema. There is evidence that there are individual differences in distinctive feature and schema learning, their storage, and retrieval.

Auditory Discrimination

In associational learning, the student must be able to discriminate the sounds he is to hook up to the printed stimulus. The point which some have made with regard to reading is that some cases of reading difficulty are produced by poor auditory discrimination. The literature on auditory discrimination and reading leads one to conclude that in the absence of frank sensory impairment, reading difficulty is probably not strongly associated with lack of auditory discrimination. Within a linguistic environment, each person tends to hear those sounds which signal a meaningful difference.

In associational learning, however, the learner must be able to discriminate the sounds, phonemes, morphemes, etc., which are to be hooked up with the stimulus. For most children learning to read, the English language, its phonology, and its syntax have been mastered. Thus, when a letter sound, or a word is presented, in most cases he can discriminate it.

Short-Term Memory

The information in short-term memory is believed to be auditory in form and survives for about 15 seconds if it is not recoded or rehearsed. The content of short-term memory originates from two sources. One source of information for short-term memory is from visual input. The visual input is recoded verbally, thus moving into short-term memory. The other source is directly from auditory input.

Although auditory discrimination does not seem to be an important problem for the student learning to read, memory for letter names, sounds, or words appears to be of greater importance. In order for associational learning to occur, there must be memory for the S-term and the R-term. Research on short-term memory indicates that if the verbal information is rehearsed or recoded, it can survive and become part of long-term memory.

Mediation or Hookup

In the learning-to-read paradigm, the hookup is between a visual stimulus and an auditory stimulus. The research on the hookup stage includes mediational strategies, imagery, use of mnemonics, and syntactic elaboration. The function of these strategies may simply be to facilitate the learning and recall of the S-term and the R-term. The actual linkage, hookup, or association between the visual and auditory stimuli may actually depend upon neurochemical processes.

Long-Term Memory

Information in long-term memory survives for an extended period of time. In terms of the model of associational learning, the content of long-term memory has three sources: input from visual memory, input from auditory short-term memory, and input from the visual-stimulus, auditory-stimulus hookup stage. When associational learning is complete, the presentation of the visual stimulus should lead to the learner giving the appropriate verbal response.

Having delineated components within the model of associational learning, it is necessary at this point to consider how the research worker in reading can test these components. Fortunately, for each of the components, descriptions of suitable methods are available. Descriptions of methods for testing each of the components can be found by referring to the following sources: for measuring attention in classroom settings, see Lahaderne (1968); for distinctive feature learning, see Pick (1965); for visual memory, see Anderson and Samuels (1970); for auditory discrimination, see Melmed (1970); for auditory memory, see Martin (1967); and for mediational strategies, see Martin, Cox, and Boersma (1965). Numerous other approaches to the investigation of the components of the model can be found in the review section of this paper.

The selection of subjects for the study and design of the research are straightforward but not simple because several important decisions must be made. The subjects for the study should be first-graders and should, in order to eliminate a possible confounding influence on the criterion variable, be learning to read by the same instructional method. One important decision that will have to be made relates to sample size, and this depends on the number of variables tested in the study. Another decision has to do with how the sample should be selected. Subjects could be selected using either a random or a stratified random procedure. If stratified random sampling is used, decisions will have to be made regarding which variables to "block."

The design of the research is correlational. However, rather than correlate one or two variables with the criterion variable, in this study the objective is to test all the components of the model. As early in grade one as possible, data from each student in the sample is fathered on attention, distinctive-feature learning, visual and auditory memory, auditory discrimination, mediation, and intelligence. At the end of the school year, the students are given reading-achievement tests. The various predictor variables are then correlated with the criterion variable and with each other. A multiple-regression analysis will provide information on the relative contribution of each of the predictor variables (i.e., the components of the model of associational learning) to reading

achievement. One of the important advantages of this analysis is that individual variability in intelligence and its contribution to reading is statistically controlled. This is essentially what the matched-group designs have been attempting to do, but always with the accompanying problems described by Campbell and Stanley (1963) and Hopkins (1969). Thus, this design and analysis enables us to compare high and low achieving students while avoiding the matched-group fallacy. Other analyses are also possible so that one can examine the intercorrelations of all predictor variables with each other as well as with the criterion variables.

REFERENCES

Anderson, R., & Samuels, S. J. Relationship between visual recognition, memory, paired-associate learning, and reading. Paper presented at the meeting of the American Educational Research Association, Minneapolis, 1970.

Arnold, R. D. 1965-66 (year two) findings, San Antonio Language Research Project. Austin: University of Texas, 1968.

Atkinson, R. C., & Shiffrin, R. M. Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), The psychology of learning and motivation: Advances in research and theory. Vol. II. New York: Academic Press, 1968.

Averback, E., & Sperling, G. Short-term storage of information in vision. In C. Cherry (Ed.), Information theory: Proceedings of the fourth London symposium. London: Butterworth, 1961.

Baker, R. W., & Madell, T. O. A continued investigation of susceptibility to distraction in academically underachieving and achieving male college students. Journal of Educational Psychology, 1965, 56, 254-258.

Bamber, D. Reaction times and error rates for same-different judgments of multidimensional stimuli. Perception and Psychophysics, 1969, 6, 169-174.

Baratz, J. C., & Shuy, R. W. Teaching black children to read. Washington, D.C.: Center for Applied Linguistics, 1969.

Bartlett, F. C. Remembering: A study in experimental and social psychology. England: Cambridge University Press, 1932.

Belloni, M. The relationship of the orienting reaction and manifest anxiety to paired-associates learning.

Unpublished doctoral dissertation, University of California, Los Angeles, 1964.

Benton, A. L. Dyslexia in relation to form perception and directional sense. In J. Money (Ed.), Reading disability. Baltimore: Johns Hopkins Press, 1962.

Bernbach, H. A. Stimulus learning and recognition in paired-associate learning. Journal of Experimental Psychology, 1967, 75, 513-519.

Bernstein, B. Language and social class. British Journal of Sociology, 1960, 11, 271-276.

Birch, H. G., & Belmont, L. Auditory-visual integration in normal and retarded readers. American Journal of Orthopsychiatry, 1964, 34, 852-861.

Bond, G. L. Auditory and speech characteristics of good and poor readers. Contributions to Education, No. 567. New York: Teachers College, Columbia University, 1935.

Bonsall, C., & Dornbush, R. L. Visual perception and reading ability. Journal of Educational Psychology, 1969, 60, 294-299.

Brackbill, Y. Arousal: Implications for a learning-to-read paradigm. Project Literacy Reports. Ithaca, N. Y.: Cornell University, 1964.

Brewer, W. F. Paired-associate learning of dyslexic children. Unpublished doctoral dissertation, University of Iowa, 1967.

Brown, J. Some tests of the decay theory in immediate memory. Quarterly Journal of Experimental Psychology, 1958, 10, 12-21.

Bryant, N. D. Learning disability in reading. In H. Newman (Ed.), Reading disabilities. New York: Odyssey Press, 1969.

Buckland, P. The effect of visual perception training on reading achievement in low-readiness first-grade pupils. Unpublished doctoral dissertation, University of Minnesota, 1969.

Busby, W. A., & Hurd, D. E. Relationship between auditory and visual perceptual ability and reading achievement. Paper presented at the meeting of the American Educational Research Association, Chicago, 1968.

Campbell, D. T., & Stanley, J. C. Experimental and quasi-experimental designs for research on teaching. In N. L.

Gage (Ed.), Handbook for research on teaching. Chicago: Rand McNally, 1963.

Cason, H. The influence of attitude and distraction. Journal of Experimental Psychology, 1938, 22, 532-546.

Clark, A. D., & Richards, C. J. Auditory discrimination among economically disadvantaged preschool children. Exceptional Children, 1966, 33, 259-262.

Conrad, R. Acoustic confusion in immediate memory. British Journal of Psychology, 1964, 55, 75-83.

Critchley, M. Developmental dyslexia. London: William Heinemann, 1964.

Davidson, R. E. Mediation and ability in paired-associate learning. Journal of Educational Psychology, 1964, 55, 352-356.

Deutsch, C. Auditory discrimination and learning: Social factors. Merrill-Palmer Quarterly, 10, 1964.

Deutsch, C. P., & McArdle, M. Development of auditory discrimination: Relationship to reading proficiency and to social class. Project Literacy Reports. Ithaca, N. Y.: Cornell University, 1967.

Doob, L. W. Eidetic images among the Ibo. Ethnology, 1964, 3, 357, 363.

Doob, L. W. Exploring eidetic and other imagery among the Kamba of central Kenya. Journal of Social Psychology, 1965, 67, 3-22.

Durrell, D. D. Improving reading instruction. New York: Harcourt, Brace & World, 1940.

Dykstra, R. The relationship between selected reading readiness measures of auditory discrimination and reading achievement at the end of first grade. Unpublished doctoral dissertation, University of Minnesota, 1962.

Early, M. What does research tell the classroom teacher about basic causes of reading disability and retardation. In H. Newman (Ed.), Reading disabilities: Selections on identification and treatment. New York: Odyssey Press, 1969.

Eriksen, C. W., & Johnson, H. J. Storage and decay characteristics of nonattended auditory stimuli. Journal of Experimental Psychology, 1964, 68, 28-36.

Farley, F. H., & Manske, M. E. The relationship of individual differences in the orientating response to complex learning kindergarteners. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1969.

Frostig, M., et al. A developmental test of visual perception for evaluating normal and neurologically handicapped children. Perceptual and Motor Skills, 1961, 12, 383-394.

Gagné, R. M. The acquisition of knowledge. Psychological Review, 1962, 69, 355-365.

Gates, A. I. A further evaluation of reading-readiness tests. Elementary School Journal, 1940, 577-591.

Gibson, E. J. A systematic application of the concepts of generalization and differentiation to verbal learning. Psychological Review, 1940, 47, 196-229.

Gibson, E., et al. An analysis of critical features of letters, tested by a confusion matrix. A Basic Research Program on Reading, Cooperative Research Project No. 639. Ithaca, N. Y.: Cornell University, 1963.

Gibson, E. J., Schapiro, F., & Yonas, A. Confusion matrices for graphic patterns obtained with a latency measure. In The analysis of reading skill: A program of basic and applied research. (Cornell University and U.S. Office of Education, Final Report, Project No. 5-1213) Ithaca, N. Y.: Cornell University Press, 1968.

Gilbert, L. C. Speed of processing visual stimuli and its relation to reading. Journal of Educational Psychology, 1959, 50, 8-14.

Goetzinger, C. P., Dirks, D. D., & Baer, C. J. Auditory discrimination and visual perception in good and poor readers. Annals of Otology, Rhinology, and Laryngology, 1955, 46, 375-380.

Goins, J. T. Visual perceptual abilities and early reading progress. Supplementary Educational Monographs, No. 87. Chicago: University of Chicago Press, 1958.

Goldmark, B. The relation of visual perception, auditory perception, and one aspect of conceptualization to word recognition. Unpublished doctoral dissertation, University of Arizona, 1964.

Guttman, N., & Julesz, B. Lower limits of auditory periodicity analysis. Journal of Acoustical Society of America, 1963, 35, 610.

Haber, R. N., & Haber, R. B. Eidetic imagery: I. Frequency. Perceptual Motor Skills, 1964, 19, 131-138.

Harrington, M., & Durrell, D. D. Mental maturity vs. perceptual ability in primary reading. Journal of Educational Psychology, 1955, 46, 375-380.

Harrington, M., & Durrell, D. D. Mental maturity vs. perception in good and poor readers. Annals of Otology, Rhinology, and Laryngology, 1960, 69, 121-136.

Hendrickson, L., & Muehl, S. The effect of attention and motor response pretraining on learning to discriminate B and D in kindergarten children. Journal of Educational Psychology, 1962, 53, 236-241.

Hinshelwood, J. Congenital word-blindness. London: H. K. Lewis, 1917.

Hopkins, K. D. Regression and the matching fallacy. Paper presented at the AERA Presession on Experimental Design and Analysis, University of Colorado, 1969.

Horn, T. D. Capsule description of San Antonio language-bilingual research project. Austin: University of Texas, 1969.

Horn, T. D., & Arnold, R. D. Capsule description of San Antonio language-bilingual research project. Austin: University of Texas, 1969.

Isom, J. B. An interpretation of dyslexia. Paper presented at the meeting of the International Reading Association, Boston, 1968.

Jeffrey, W. E. Variables in early discrimination learning. I. Motor responses in the training of a left-right discrimination. Child Development, 1958, 29, 269-275.

Jerrolds, B. W., Callaway, B., & Gwaltney, A. A comparative study of three tests of intellectual potential, three tests of reading achievement, and the discrepancy scores between potential and achievement. Journal of Educational Research, 1971, in press.

Kaplan, G. A., Yonas, A., & Shurcliff, A. Visual and acoustic confusability in a visual search task. Perception and Psychophysics, 1966, 1, 172-174.

Krise, M. An experimental investigation of theories of reversal in reading. Journal of Educational Psychology, 1952, 43, 408-422.

Labov, W. Some sources of reading problems for Negro speakers of nonstandard English. In J. Baratz & R. Shuy (Eds.), Teaching black children to read. Washington, D.C.: Center for Applied Linguistics, 1969.

Lahaderne, H. M. Attitudinal and intellectual correlates of attention: A study of four sixth-grade classrooms. Journal of Educational Psychology, 1968, 59, 320-324.

Lenneberg, E. H. A biological perspective on language. In E. H. Lenneberg (Ed.), New directions in the study of language. Cambridge, Mass.: M.I.T. Press, 1964.

Lyle, J. G., & Goyen, J. Visual recognition, developmental lag, and strephosymbolia in reading retardation. Journal of Abnormal Psychology, 1968, 73, 25-29.

Maltzman, I., & Raskin, D. C. Effects of individual differences in the orienting reflex on conditioning and complex processes. Journal of Experimental Research in Personality, 1965, 1, 1-16.

Martin, C., Cox, D., & Boersma, F. The role of associative strategies in the acquisition of P-A material: An alternative approach to meaningfulness. Psychonomic Science, 1965, 3, 463-464.

Martin, E. Relation between stimulus recognition and paired-associate learning. Journal of Experimental Psychology, 1967, 74, 500-505.

McCarthy, J. J., & McCarthy, J. F. Learning disabilities. Boston: Allyn & Bacon, 1969.

McGuire, W. A multiprocess model for paired-associate learning. Journal of Experimental Psychology, 1961, 62, 335-347.

Melmed, P. J. Auditory discrimination and the reading process in relation to the nonstandard English speaker, 1970. (Mimeographed)

Meltzer, N. S., & Herse, R. The boundaries of written words as seen by first graders. The Journal of Reading Behavior, 1969, 1, 3-13.

Mitchell-Kernan, C. Language behavior in a black urban community. Unpublished doctoral dissertation, University of California, Berkeley, 1969. Also Working Paper No. 23, Language-Behavior Research Laboratory, University of California, Berkeley, 1969.

Modiano, N. National or mother language in beginning reading: A comparative study. Research in the Teaching of English, 1968, 1, 32-43.

Money, J. Dyslexia, a postconference review. In J. Money (Ed.), Reading disability. Baltimore: Johns Hopkins Press, 1962.

Monroe, M. Children who cannot read. Chicago: University of Chicago Press, 1932.

Monroe, M. Reading aptitude tests for the prediction of success and failure in beginning reading. Education, 1935, 7-14.

Morikawa, Y. Functions of stimulus and response in paired-associate verbal learning. Psychologia, 1959, 2, 41-56.

Neisser, U. Cognitive psychology. New York: Appleton-Century-Crofts, 1967.

Norman, D. A. Memory and attention. New York: Wiley, 1969.

Olson, A. V. School achievement, reading ability, and specific visual perception skills in the third grade. The Reading Teacher, 1966, 19, 490-492.

Orton, S. T. Reading, writing, and speech problems in children. New York: W. W. Norton, 1937.

Otto, W. The acquisition and retention of paired associates by good, average, and poor readers. Journal of Educational Psychology, 1961, 52, 241-248.

Penfield, W. Memory mechanisms. A.M.A. Archives of Neurological Psychiatry, 1952, 67, 178-191.

Penfield, W. The permanent record of the stream of consciousness. Proceedings of the 14th International Congress of Psychology, Montreal Neurological Institute, 1954, Report No. 486.

Penfield, W. Some mechanisms of consciousness discovered during electrical stimulation of the brain. Proceedings of the National Academy of Sciences, 1958, 44, 51-66.

Peterson, L. R., & Peterson, M. L. Short-term retention of individual verbal items. Journal of Experimental Psychology, 1959, 58, 193-198.

Pick, A. D. Improvement of visual and tactual form discrimination. Journal of Experimental Psychology, 1965, 69, 331-339.

Pick, A., Pick, H., Jr., & Thomas, M. Cross-model transfer and improvement of form discrimination. Journal of Experimental Child Psychology, 1966, 3, 279-288.

Poling, D. L. Auditory deficiencies of poor readers. Clinical Studies in Reading, II. Supplementary Educational Monographs, 1953, 77, 107-111.

Popp, H. M. Visual discrimination of alphabet letters. The Reading Teacher, 1964, 1, 221-225.

Posner, M. I., & Konick, A. F. On the role of interference in short-term retention. Journal of Experimental Psychology, 1966, 72, 221-231.

Rabinovitch, R. D. Dyslexia: Psychiatric considerations. In J. Money (Ed.), Reading disability. Baltimore: Johns Hopkins Press, 1962.

Reed, J. C. The deficits of retarded readers--fact or artifact? The Reading Teacher, 1970, 23, 347-352.

Reynolds, M. C. A study of the relationships between auditory characteristics and specific silent reading abilities. Journal of Educational Research, 1953, 46, 439-449.

Robinson, H. M. Why pupils fail in reading. Chicago: University of Chicago Press, 1946.

Rohwer, W. Mental elaboration and proficient learning. In J. P. Hill (Ed.), Minnesota Symposia on Child Psychology. Vol. 4. Minneapolis: University of Minnesota Press, 1970.

Rosen, C. I. A study of visual perception capabilities of first grade pupils and the relationship between visual perception training and reading achievement. Unpublished doctoral dissertation, University of Minnesota, 1965.

Rosner, J. Phonic analysis training and beginning reading skills. Learning Research and Development Center, University of Pittsburgh, 1971.

Rudegeair, R. E., & Kamil, M. L. Assessment of phonological discrimination in children. Madison: Center for Cognitive Learning, University of Wisconsin, 1970.

Rystrom, R. Negro speech and others: A reply. Reading Research Quarterly, 1970, 6, 123-125.

Samuels, S. J. Attentional processes in reading: The effect of pictures on the acquisition of reading responses. Journal of Educational Psychology, 1967, 58, 337-342.

Samuels, S. J. Relationship between formal intralist similarity and the von Restorff effect. Journal of Educational Psychology, 1968, 59, 432-437.

Samuels, S. J. The effect of simultaneous versus successive visual discrimination training on paired associate learning. Journal of Educational Psychology, 1969, 60, 46-48.

Samuels, S. J. An experimental program for teaching letter names of the alphabet. Project No. 9-F-009. Washington, D.C.: U.S. Office of Education, 1970. (a)

Samuels, S. J. Interaction of list length and low stimulus similarity on the von Restorff effect. Journal of Educational Psychology, 1970, 61, 57-58. (b)

Samuels, S. J. Reading disability? The Reading Teacher, 1970, 23, 267-283. (c)

Samuels, S. J., & Jeffrey, W. E. Discriminability of words and letter cues used in learning to read. Journal of Educational Psychology, 1966, 57, 337-340.

Savin, H. B. What the child knows about speech when he starts to learn to read. Philadelphia: University of Pennsylvania, 1971.

Schonell, F. J. Backwardness in the basic subjects. Edinburgh: Oliver & Boyd, 1948.

Senf, G. M. Development of immediate memory for bisensory stimuli in normal children and children with learning disorders. Developmental Psychology Monograph, 1969.

Shepard, R. N., & Teghtsoonian, M. Retention of information under conditions approaching a steady state. Journal of Experimental Psychology, 1961, 62, 302-309.

Silverman, M., Davids, A., & Andrews, J. M. Powers of attention and academic achievement. Perceptual and Motor Skills, 1963, 17, 243-249.

Sperling, G. The information available in brief visual presentation. Psychological Monographs, 1960, 74. (Whole No. 498)

Sperling, G. A model for visual memory tasks. Human Factors, 1963, 5, 19-31.

Spring, C. Same-different reaction time for letters in dyslexic and normal children. Unpublished doctoral dissertation, University of California, Davis, 1969.

Staats, A. W., & Staats, C. K. Complex human behavior. New York: Holt, Rinehart, & Winston, 1963.

Steinheiser, F. H. Phonemic distinctive-feature encoding from visual information storage. Unpublished doctoral dissertation, University of Cincinnati, 1970.

Stewart, W. On the use of Negro dialect in the teaching of reading. In J. Baratz & R. Shuy (Eds.), Teaching black children to read. Washington, D.C.: Center for Applied Linguistics, 1969.

Strickland, R. The language of elementary school children: Its relationship to the language of reading textbooks and the quality of reading of selected children. Bloomington: School of Education, Indiana University, 1962.

Templin, M. Certain language skills in children. Minneapolis: University of Minnesota Press, 1957.

Travers, R. Perceptual learning. Review of Educational Research, 1967, 5, 599-619.

Turnure, J. E. Children's reactions to distracters in a learning situation. Developmental Psychology, 1969, 2, 115-122.

Turnure, J. E., & Walsh, M. The effects of varied levels of verbal mediation on the learning and reversal of paired-associates by educable mentally retarded children. Technical Report No. 6, Research and Development Center in Education of the Handicapped. Minneapolis: University of Minnesota Press, 1970.

Underwood, B. J., & Schulz, R. W. Meaningfulness and verbal learning. New York: Lippincott, 1960.

UNESCO The use of vernacular languages in education. Monographs on Fundamental Education, No. 8. Paris: UNESCO, 1953.

Venezky, R. L. Nonstandard language and reading. Wisconsin Research and Development Center for Cognitive Learning, Madison, Wisconsin, 1970.

Vernon, M. D. Backwardness in reading: A study of its nature and origin. Cambridge: Cambridge University Press, 1957.

Wardhaugh, R. Reading: A linguistic perspective. New York: Harcourt, Brace & World, 1969.

Waugh, N. C., & Norman, D. A. The measurement of interference in primary memory. Journal of Verbal Learning and Verbal Behavior, 1968, 7, 617-626.

Weber, R. M. Sone reservations on the significance of dialect differences to the acquisition of reading. Paper presented at the meeting of the International Reading Association, Anaheim, California, 1969.

Weener, P. D. Social dialect differences and the recall of verbal messages. Journal of Educational Psychology, 1969, 60, 194-199.

Weiner, P. S. Auditory discrimination and articulation. Journal of Speech and Hearing Disorders, 1967, 32, 19-28.

Wepman, J. Auditory discrimination, speech and reading. Elementary School Journal, 1960, 3, 325-333.

Wheeler, L. R., & Wheeler, V. D. A study of the relationship of auditory discrimination to silent reading abilities. Journal of Educational Research, 1954, 48, 103-113.

Wiener, M., & Cromer, W. Reading and reading difficulty: A conceptual analysis. Harvard Educational Review, 1967, 47, 620-643.

Williams, J. P. Training kindergarten children to discriminate letter-like forms. American Educational Research Journal, 1969, 6, 501-514.

Williams, J. P., & Ackerman, M. D. Simultaneous and successive discrimination learning as a function of stimulus similarity. Paper presented at the meeting of the American Educational Research Association, Washington, 1968.

Wolfe, L. S. Differential factors in specific reading disability. Journal of Genetic Psychology, 1941, 58, 57-69.

Zeaman, D., & House, B. J. The relation of IQ and learning. In R. M. Gagné (Ed.), Learning and individual differences. Columbus, Ohio: Charles E. Merrill, 1967.

THEORIES, MODELS, AND STRATEGIES FOR LEARNING TO READ

Harry Singer

University of California, Riverside

INTRODUCTION

Although evidence has been accumulating for some time on the effect of various methods and strategies for teaching reading, only recently have models been constructed to represent the variables involved in reading and theories been formulated to explain the processes of decoding, comprehending, and encoding of printed messages (Holmes & Singer, 1964; Singer & Ruddell, 1970).

These models, as well as theories and research on cognitive, linguistic, and emotional-social development, indicate that qualitative and quantitative changes in theoretical formulations and models of reading behavior are necessary for each stage of development (Athey, 1970; Singer, 1965a, 1969). Consequently, only those theories, models, and strategies that focus on the initial stages of acquisition of reading are included in this review. First, we shall summarize methods of teaching reading, and then, in order, learning theories and strategies, linguistic theories, and finally, reading theories and models for learning to read.

METHODS OF TEACHING READING

In the history of American reading instruction (Smith, 1965), the unit of initial instructional emphasis has varied in a surprisingly systematic way from the smallest to the largest stimulus. At first, the unit of emphasis was the letter. The alphabet method with its emphasis on spelling put a premium on memorization processes for learning to read. Next on the continuum was phonics with its emphasis on word parts (digraphs, blends, syllables, affixes) and on association of sounds with their printed counterparts. It put a premium on auditory discrimination and pronunciation. Further on the continuum was the whole word as the stimulus unit, association between printed word and picture. Visualization was regarded as the primary mode of learning. The extreme end of the continuum was the experience-chart method with the

sentence or paragraph as the initial stimulus unit. It put stress upon meaningful context or experience of children and on the cumulations of expectancies and linguistic redundancies for providing adequate stimulus input, clarifying meanings, and confirming word recognition predictions (Singer, 1966, 1968).

For some time the basal-reader method dominated American reading instruction (Austin & Morrison, 1963). But, as a result of considerable experimentation over the past ten years, the stimulus or input instructional unit now emphasized in American classrooms covers the entire continuum from the alphabet method to the paragraph or whole-story method (Chall, 1967).

Regardless of the instructional method employed, the age-equivalent range of achievement in a heterogeneous classroom will still approximate two-thirds of the chronological age of the group even if all the children in the class are, in fact, reading at a level equal to their mental-age expectancies (Bond & Tinker, 1967). Consequently, the significant scientific and pedagogical question is not the often-asked, but meaningless, question of whether one method is better than another. Instead, the questions we should ask are: How do individuals learn to decode print to speech? To what extent do variations in method or initial units and sequences of instruction have to be adapted to individual differences in learners? What are the short- and long-range effects of differing input strategies upon the reading progress of various groups of children?

Although a multitude of questions on acquisition of reading ability still need to be answered (Gibson, 1970), there are only two major classes of learning theories, stimulus-response theories and cognitive or field theories, to draw upon in designing models for teaching reading.

LEARNING THEORY FOR TEACHING READING

Stimulus-Response Models

Thorndike's model for reading instruction was based on his stimulus-response theory of learning. Assuming that the unit of perception in learning to read is the whole word, Thorndike argued that learning to read depends on acquisition of correct oral responses to printed words. All the teacher has to do in teaching children to read is to expose each stimulus word to the pupil, identify its correct oral response, and upon subsequent exposures of the printed word, provide satisfying consequences for correct responses from the pupil.

To increase the probability of obtaining satisfying consequences and to make reading of immediate value, Thorndike

recommended that the most frequently occurring words be taught first. This reasoning led Thorndike to construct his Teachers Word Book (Thorndike, 1921, 1931; Thorndike & Lorge, 1944), which became the vocabulary source for almost all present-day basal readers. Thorndike's theory of learning applied to reading instruction was also adopted as the basal readers' instructional rationale. Even the round-robin, or reading-in-a-circle, procedure widely used today in first-grade classrooms is based on the Thorndikian model for teaching reading (Singer, 1970a). His model is also used for teaching correct responses to constituent parts of words, such as occur in phonics and structural-analysis skills in basal readers (Singer, 1971). Because the words used and the ideas represented in basal readers are usually within the average first-grader's vocabulary and experiential repertoire, oral responses or oral reconstruction of printed words is supposed to lead to association of meaning (Carroll, 1964) but can result simply in recoding the printed message into an oral rendering.

Two other S-R theories (first, Skinner's reinforcement of emitted responses with its concept of the shaping of behavior and its use of reinforcement schedules and, second, conditioning theory) have been employed by Staats (1965, 1968; Staats et al., 1970) to explain the acquisition of accurate responses to printed stimuli. Using an instructional apparatus based upon Skinnerian theory, Staats has demonstrated that children (even preschoolers, remedial readers, and delinquents) can be trained, at least in the initial stages of learning to read, to decode printed stimuli to speech, and to associate meaning with the spoken word. Others, such as Ellson et al. (1965), have conducted similar demonstrations with programmed instructional material. Moore (1961) has successfully adapted Skinnerian theory to a "talking typewriter," later called an autolelic or responsive learning environment, and has taught three-year-olds to decode printed words.

Thorndikian and Skinnerian theories are quite limited in formulating research to discover cognitive and affective phenomena in reading because both of these theories eschew conceptualization of intervening variables and hypothetical constructs. Specifically, no attempt has been made in either S-R or Skinnerian theory to explain how and why the learner can acquire, organize, store, and reorganize information; formulate his own purposes; and mobilize appropriate subsystems for responding to the printed page (Singer, 1962, 1966). Of course, S-R theory can explain how individuals can learn to discriminate, abstract, and generalize, but S-R theory does not attempt to explain or predict the formation of perceptual and cognitive systems. Essentially, then, the Thorndikian and Skinnerian models do not take into consideration the underlying competencies of the learner for acquiring, selecting, processing, organizing, and utilizing a repertoire of conceptual systems for actively responding to the printed page (Chomsky, 1965; Singer, 1966).

However, if the cognitive, linguistic, and affective capabilities of the human learner were added so that S-R theory became an explicitly formulated stimulus-organism-response or S-O-R model, perhaps using a mediational-response concept (Osgood, 1953; Woodworth, 1929), hypotheses could be derived and tested to determine conditions for developing the capacities of learners into an adequate cognitive system for reducing and processing the mass of detailed information necessary for responding accurately and meaningfully to printed words. Also, instructional conditions for developing and integrating affective, conative, linguistic, and cognitive systems of the individual might also be discovered and incorporated into S-O-R theory. Some research along these lines has already been conducted (Athey, 1965; Athey & Holmes, 1969; Davis, 1964).

For theoretical and educational purposes, merely developing accurate responses to printed words is not enough; theory and instruction must take the individual from correct responses to printed stimuli under extrinsic motivation to critical and creative reading performance under intrinsic motivation. This developmental transition from a conditioning or stimulus-response mode to a cognitive mode of learning has been attributed by Holmes (1965) to the formation of "mobilizers," psychocatalytic mechanisms derived from the establishment of value systems and attitudes conducive to the realization of self-actualized goals and purposes in reading. These value systems are more likely to arise when individuals have been reared under conditions that have taught them to resolve their developmental, emotional conflicts in a positive direction of trust, autonomy, initiative, industry, and love (Athey, 1970).

Field- or Cognitive-Learning Theory Models

An active, purposeful, and flexible mode of response to printed words can be developed from the beginning of formal reading instruction through field theories of learning, which stress such concepts as purposeful behavior, knowledge of means-ends relationships, and various routes to goal achievement. Although not as systematically employed in instruction as S-R theories, field- or cognitive-learning theory models can be recognized in such approaches to teaching reading as the language-arts and individualized-reading methods.

Emphasis in the language-experience method is on (a) starting the learner with a meaningful sentence or paragraph based on his experience and expressed in his own words, (b) establishing purpose, (c) developing expectancies for word recognition and meaning through the use of context, and (d) focusing on the paragraph's constituent words and word elements. Through grouping of words with common elements,

stress is placed upon having pupils learn to conceptualize; that is, to discriminate, abstract, and generalize phoneme-grapheme correspondences, morphemes, spelling patterns, and syntactic structures. Stress is also placed on other units consistent with rules of word recognition and with establishing a set for diversity (Levin & Watson, 1963) or for flexibility in word recognition (Singer, 1966).

In essence, the language-experience approach maximizes correspondence of the printed message with the language of the reader; consequently, when he does read, his language-competence system is activated and his comprehension is therefore likely to be optimal (Ruddell, 1965a, 1969). At first, the pupil learns to read his own words and then the words of others through an individualized reading program that features self-selection of books or satisfaction of curiosity as a motive for reading (Singer, 1965b).

Laboratory Investigations

In addition to experimentation based upon different learning-theory models, laboratory investigations have been conducted on paired-associate learning. Under the more carefully controlled conditions of the laboratory, albeit a somewhat artificial situation, some questions on learning to read have been studied.

Defining learning to read as decoding print to speech, Gibson divided the process into a sequence of four components: (a) acquisition of speech prior to reading, (b) discrimination of graphemes, (c) decoding letters to sounds, and (d) shifting from lower- to higher-order units or from phoneme-grapheme relationships to spelling patterns; that is, clusters of graphemes in a given environment which have an invariant pronunciation according to the rules of English (Fries, 1962; Gibson, 1965).

Pick (1965) determined that discrimination of letters is initially learned through instructional emphasis upon discovery of attributes or distinctive features of letters by perceiving contrasting pairs of letters. Later, discrimination of letters occurs through the formation of schemas or prototypes, a kind of model or memory image of the letter, built up and stored as a result of repeated presentation of letters. Then, matching sensory experiences to the previously stored concept or model of the letter, the learner can correctly identify the letter.

Transfer seems to depend on ability to relate oral sounds to graphic configurations at both initial and mature stages of reading. Bishop (1964) found that adults could learn to associate sounds with artificial words through

repeating the sounds corresponding to the artificial words without instruction in the component letter-sound correspondences. However, transfer of the skill to new words depended on learning letter-sound correspondences directly through instruction or indirectly by abstracting them in the process of responding to words. Jeffrey and Samuels (1967) reported that kindergarten children, taught to recognize a group of words by a phonic method, read more new words made up of the same letters and learned the new word list significantly faster than the experimental group taught by the look-say method. The latter group performed in the transfer situation about the same as a control group. However, deaf children perform like hearing children in utilizing pronounceable and unpronounceable spelling patterns (Gibson et al., 1970).

The size and complexity of higher-order units (spelling and morphological patterns) increase with development of reading skill. Gibson, Osser, and Pick (1963) compared first- and third-graders with respect to tachistoscopic perception and recall of the spellings of pronounceable and unpronounceable trigrams made up of the same letters. The first-graders performed better on the pronounceable trigrams than on the unpronounceable trigrams. The third-graders performed equally well on both types. These results did not hold for four- or five-letter pronounceable pseudo words. The authors concluded that children, by the end of first grade, tend to read in short units and have already generalized certain regularities of spelling-to-sound correspondence. By the end of third grade, they have increased their span of recognition to four- or five-letter words, which involve more complex conditional rules and more complex clusters of spelling-to-sound correspondences.

In agreement with Fries (1962), Gibson suggested that discovery of these rules might be enhanced if reading materials were programmed according to spelling patterns. Confirming this hypothesis, Skailand (1970) found that low socioeconomic kindergarten pupils taught by spelling patterns recalled about twice as many syllables and words as those taught by whole words or single phoneme-grapheme patterns.

The order of ease of perception for words in isolation is (a) real words, meaningful and pronounceable according to spelling patterns; (b) nonword pronounceable strings of letters; and (c) meaningful but unpronounceable letter strings (Gibson, Bishop, Schiff, & Smith, 1964). Gibson (1965) wisely points out that the role of meaning probably increases in sentences in which semantic and syntactic constraints not only make sentences "memorable" and "intelligible," but also serve as "unit formers" for word perception. She also recognizes that learning to read involves more than just learning the four components she has listed. In particular, she notes that several strategies have to be evaluated and incorporated into instructional processes and decision-making.

Strategies in Word Recognition

Without guidance or stimulus control, children adopt the strategy of recognizing words by using the easiest cue. This may be an initial letter group, word shape, or any discernible attribute, even an idiosyncratic one or an incidental detail (Samuels, 1970). Pictures associated with words may hinder word recognition under some conditions for poor readers (Samuels, 1967), but appear to facilitate it under other conditions (Hartley, 1970). Perhaps pictures are useful in the initial stages of learning as a bridge from concrete to symbolic learning, but if they are not phased out, they may foster dependence. A developmental test of this hypothesis may be necessary to resolve the apparent discrepancy between Samuels' and Hartley's results. At least, Biemiller (1970) found that oral readers develop through dependence on context for meaningful guesses to making no response, indicating their awareness of the graphic features of unknown words and of their inability to recognize them. They attain increased skill in using graphic information and subsequently become able to integrate information about the graphic features of words with syntactic and semantic constraints. Because some beginning readers may become too dependent on contextual and picture cues in the initial phase, Biemiller suggests that teachers promote development by omitting contextual and picture cues and compelling children to rely upon graphic information as much as possible. Contextual material may be added as children acquire graphic skills.

Children can be taught to use a particular cue, but not necessarily a relevant one, for transfer. For example, when color cues were used in teaching words, children learned to recognize color-cued words more rapidly than noncolor-cued words. But when color cues were removed, the children had difficulty in recognizing the words; apparently they had not transferred the color cues to their associated word parts (Samuels, 1968). Samuels and Jeffrey (1966) also found that kindergarten children learned to recognize two-letter <u>dissimilar</u> words, such as <u>da</u>, <u>be</u>, <u>mi</u>, and <u>so</u>, more rapidly than two-letter <u>similar</u> words, such as <u>me</u>, <u>ma</u>, <u>se</u>, and <u>sa</u>. But in the transfer situation, the dissimilar group made more errors because they had learned and used only single-letter cues. Thus, a strategy for speed of initial learning was not so effective as a strategy for slower rate of learning with more effective transfer.

Although children learned initially to discriminate letters according to their attributes, the order in which the letters are taught makes a difference in rate of learning. Williams and Ackerman (1971) found that highly similar letters, such as <u>b</u> and <u>d</u>, were easier to learn to discriminate when they were taught successively. But for dissimilar letters, such as <u>s</u> and <u>b</u>, simultaneous discrimination training

was easier. They reasoned that similar letters presented simultaneously offered so many attributes at one time that acquisition of the discriminating attributes was hindered.

However, for flexibility in responding to printed stimuli when alternate responses are available for a particular grapheme, such as city or cow, concurrent rather than consecutive training is more beneficial. Williams (1968) reported that fifth- and sixth-graders in a modified paired-associates paradigm could remember multiple correspondences for visual stimuli better when these were taught concurrently than when they were taught consecutively. She inferred that readers who could identify graphemes as having multiple responses are more likely to switch to an alternate when one response proved to be ineffective in leading to recognition of the word. These readers are, therefore, more likely to be successful than other readers.

Evidence about adult performance in word recognition cannot be generalized to the child beginning to read (Samuels, 1970; Singer, 1970b; Williams, 1970). Williams also points out that laboratory evidence about recognition of letters and words in isolation is inadequate because it has not taken into account the linguistic constraints of semantics and syntax. When these linguistic components are taken into account, hypotheses or cumulative expectancies can be formed as a reader samples the printed stimuli that lead to predictions of words, word meanings, and ideas. These hypotheses or expectancies are confirmed or disconfirmed by subsequent samples of stimuli (Goodman, 1970; Hochberg & Brooks, 1970; Samuels, 1971).

The effect of motivation on acquisition of reading behavior also needs to be investigated. For example, what is the effect of locus of control and self-established goals upon reading acquisition and performance? In a case study, Singer and Beasley (1970) found that a severely retarded reader spent longer periods of time in reading when they gave him an opportunity to set his own goals for achievement, restructured his learning conditions (for example, by switching from words read per minute to words read per session, so that he could always attain his goal), and provided for feedback and cumulative knowledge of progress.

Further experimentation on intrinsic motivation must be undertaken, such as alternating, according to Piagetian theory, a period of assimilation of schemas (for example, recognition of new words that fit under previously induced rules) with a period of accommodation (for example, introduction of words that do not fit the previously induced rules but instead require a new rule, perhaps a rule involving a high-order unit, such as a shift from a phoneme-grapheme to a sound-spelling pattern). Or alternation might involve a

shift from reading a graphic stimulus alone to reading context plus a graphic stimulus. Context is particularly necessary for determining the pronunciation of homographs, such as "They produce food" and "They take produce to the market." Resolution of such cognitive dissonance, or reduction of uncertainty, leads to the formation of word-recognition expectancies determined by contextual and linguistic constraints and provides internal gratification and reinforcement. It may also establish a learning set for hierarchical organization. Furthermore, curiosity aroused by cognitive discrepancies may also foster active perceptual searching and, if appropriate conditions are provided, result in rule-induction behavior.

LINGUISTIC MODELS FOR READING INSTRUCTION

Linguistic models for reading instruction also vary on an instructional-unit continuum. Towards one end of the continuum, Bloomfield (1942) recommended teaching children (a) to associate regular spellings with their oral actualizations, and (b) to progress gradually to irregular spellings. Fries (1962), pointing out that spelling patterns have a closer correspondence to oral language than do phoneme-grapheme relationships, advocated the teaching of reading by the initial presentation of contrasting spelling patterns in capital letters and by the association of graphic forms with their oral responses.

Defining reading as only decoding print to speech, Reed (1965) argued that traditional phonics and whole-word methods are both faulty because phoneme-grapheme relationships are limited and the whole-word method emphasizes meaning, which is not reading, but is a consequence of reading. Instead, Reed employs the hypothetical construct of linguistic form, which links a unit of meaning to a wholly regular physical representation of speech or writing, to explain that written and spoken symbols are associated through identification of their common linguistic forms. Learning to speak consists of acquiring linguistic forms at first through trial and error, imitation, and memorization. Later, the learning comes through discriminating, abstracting, and generalizing the regularities in the grammatical and representational systems. For the child who has already learned to speak English, learning to read consists of associating graphic configurations with already-known linguistic forms. Reed stresses that only after the child has learned to speak and write his own stock of linguistic forms should he be required to use reading to learn further linguistic forms.

Towards the other end of the linguistic-models continuum, Chomsky's theory of transformational-generative grammar has been interpreted and applied to reading by several

educational research workers, such as Goodman (1968) and Rud-dell (1969). Goodman (1970) recently called for a translation of a theory of the reading process into a theory of reading instruction. In this theory, only sketchily presented, meaning is central and the basic unit of instruction is the clause. Because graphophonological, morphological, syntactical, and semantic systems interact from the beginning of instruction, Goodman points out that sequencing of components is not possible, but control over materials is necessary. If the printed materials are consistent with the child's meanings and use of oral language, the child should be able to use his linguistic competencies and the constraints and redundancies of language for forming expectancies and for predicting and confirming meanings. If predictions are not confirmed, he must use strategies for self-correction. Consequently, the beginning reader must already be somewhat competent in the use of the language and he must have a need to understand printed communication. All of these processes operate as the reader selects cues; decodes graphic stimuli through the interaction of graphophonological, syntactic, and semantic systems; and transforms the surface structure of the sentence to deep structure. He tests the meaning he has decided upon and, if necessary, corrects his initial "guesses." When the meaning of the message has been determined, he encodes his own meaning through graphic or phonological rules for overt expression. Essentially, Goodman's theory of instruction for reading is consistent with a field theory of learning and a language-experience method of teaching reading.

Thus, like methods of teaching reading, linguistic implications for teaching reading range from emphasis upon a small unit of instruction, phoneme-grapheme correspondence, to emphasis upon a larger unit of instruction, sentences that correspond to the child's meanings and use of language. The controversy in this area cannot be resolved by arguing that decoding to speech must involve meaning because it is possible to recode meaningless sentences from print to speech. Furthermore, as Goodman points out, it is possible to have a grammatical sentence without meaning, but it is not possible to have a meaningful sentence without grammar. Although the language competence of the beginning reader may be involved in various types of instruction, the models at the sentence end of the continuum described earlier are more likely than models at the other end of the continuum to call into play the language competence of the beginning reader and thus facilitate his learning.

Whether the controversy needs to be resolved depends upon the answer to such empirical questions as the following: Do the different theories lead to instructional procedures and consequences that differ in tendency to facilitate or to impede acquisition of reading ability? Are there differences in cognitive capabilities or styles of beginning readers that

are more attuned to one instructional procedure than to others? Some evidence about the effects of different instructional procedures in teaching reading can be adduced to provide insight into the issues involved in the controversy.

METHODOLOGICAL EFFECTS ON READING BEHAVIOR

Although there is a hierarchy of the skills in learning to read that start to develop as early as the child begins to talk, the evidence seems to indicate that training at the kindergarten or first-grade level on tasks other than printed stimuli is likely to be less effective than on tasks that involve graphic stimuli. Gates (1926) reported that the intercorrelations of perception of geometric symbols, numbers, and words were quite low. Yet in kindergartens today, materials are widely used that purport to prepare children for reading and that are based on motor activities (Delacato, 1959; Kephart, 1960), on visuo-motor perception (Frostig, 1964), and on visual analysis and synthesis or "try" tasks (Manolakes et al., 1967).* If perception is not a unitary function, and if there is likely to be little transfer from ability to perceive nonprinted stimuli to printed stimuli, perceptual training in reading readiness should focus on the discrimination, abstraction, and generalization of printed letters and word forms (Singer, 1966, 1970b). Most children apparently learn some letter names during or prior to kindergarten. At the beginning of grade 1, children can recognize most of the capital and at least half of the lower-case letters (Hildreth et al., 1965). Consequently, evaluation of reading readiness and subsequent activities, normally begun in grade 1, should probably be initiated earlier if children are, in fact, to be properly paced rather than forced ahead or delayed in learning to read (Singer, Balow, & Dahms, 1968).

Individual differences in reading achievement at the end of the first grade tend to be related to the method of instruction. Gates, Bond, and Russell (1939, p. 41) found that the best variables for predicting progress in beginning reading were word recognition; ability to complete a partially told story; giving words that end with the same sound as an example; blending sounds; ability to read letters of the alphabet; and ability to listen to, understand, and make use of a teacher's instruction. But they noted that "if the teacher effectively emphasizes early phonetic attack, tests of blending, rhyming, etc., are likely to give higher correlations with reading progress in her class than in another class where less emphasis is placed on the phonetic approach."

---

*Try tasks 1 and 2 consist of visual analysis and synthesis of geometric objects. Task 3 uses letter tiles to reproduce words. This task, in contrast to tasks 1 and 2, trains letter and word perception directly.

Ruddell (1965b, 1968) discovered that, if the criterion for reading instruction consisted of scores on a standardized reading test, programmed instruction was superior to the basal-reader or the whole-word approach at the end of grade 1. At the end of grade 2, with the same type of criterion, the basal-reader approach turned out to be superior. The explanation for these results appears to be that the phonics emphasized in the programmed instruction that was used taught the word-recognition skills needed for good performance at the end of the first grade. The more comprehensive set of skills taught by the basal reader over a longer period of time did not pay off until the end of the second grade. It appears that in the initial stages of reading instruction, there are some general factors, such as language and thought, that are common to a wide variety of reading tasks. But there is also a high degree of specificity. Consequently, performance in the initial stages of reading is, in part, a function of what has been specifically taught and emphasized (Singer, 1970a).

Apparently, most children can adapt to a variety of methods of instruction though each method tends to have its own set of effects. Buswell (1922), using an eye-movement camera for assessing symptoms of central mental processes in reading, compared the results of teaching reading by a phonic method with those of teaching reading by a method that emphasized meaning or content. The results indicated that the phonic method tended to promote left-to-right sequence in eye movements and word pronunciation, while the content method fostered concern for the meaning but resulted in a slower rate of progress in word recognition and rhythmic eye-movement behavior. Instead of perceiving whole words at a glance in the initial stages of instruction, Buswell found that children tend to make an average of two fixations per word.

Agnew (1939) reported that differences in methodological emphases resulted in differential effects in oral and silent reading. In word recognition and <u>oral reading</u>, the phonics-emphasis group was superior to the nonphonics emphasis group, but in <u>silent reading</u>, the two groups were about equal. These results suggest that the combination of abilities used or mobilized for <u>oral reading</u> placed a heavy premium on a phonics subskill, but for <u>silent reading</u> a quantitatively or qualitatively different combination of subabilities, or both, was used (in which phonic abilities had less weight and other subabilities had more weight).

A similar conclusion can be reached by careful reading of the largest methodological study of reading instruction ever undertaken in the United States. In this study, Bond and Dykstra (1967) compared five methodological emphases (initial teaching alphabet, basal plus phonics, language experience, linguistic, and phonics combined with linguistics) with a basal-reader approach to beginning reading. For comparison

criteria, they used word reading, paragraph meaning, spelling, and word-study skills, as these are assessed by subtests of the Stanford Achievement Test. Although Bond and Dykstra recognize serious methodological flaws in the design of the first-grade study, such as noncomparable samples, their findings at least suggest hypotheses for further research. In general, Bond and Dykstra found that the nonbasal instructional programs tended to be superior to the basal program when it was assessed with the criterion consisting of word-meaning scores at the end of the first year of reading. However, when nonbasal and basal programs were compared on the basis of comprehension, with the criterion consisting of paragraph-meaning scores, the differences were less consistent. The programs superior to the basal-reader program in the development of word-recognition skills (as assessed by the Stanford word-meaning subtest, Fry's list of phonetically regular words, and Gates's random sample of words) were i.t.a., basal-plus-phonics, linguistic, and phonics-linguistics. The language-experience approach was not in this group. The programs that were superior to the basal program in development of comprehension were the basal-plus-phonics and phonics-linguistic programs. Apparently, more emphasis upon phonics and linguistic elements than is usually encountered in a typical basal reader program and inclusion of connected reading enhance growth not only in word-recognition skills, but also in comprehension skills.

From these results we may formulate the hypothesis that different methods of teaching reading produce readers whose patterns of skills are different but whose overall level of comprehension is about the same.* This hypothesis should,

---

*Drawing upon the theoretical assertion of Chomsky (1970) that English orthography is a "near-optimal system for representing the spoken language (p. 4)" because it maintains stimulus characteristics that elicit phonological, morphological, and semantic responses, Gillooly (1971) adduces evidence to explain why initial reading instruction in i.t.a. (which attempts to regularize the spelling of all words) increases word-recognition level, but not comprehension level, to an extent greater than initial reading instruction in conventional English orthography. Singer (1971) agreed with Gillooly's conclusions and suggested the testable hypothesis that multiple-regression equations using the same morphological, lexical, and phonological variables for predicting level-of-comprehension scores would yield insignificantly different multiple correlations with the criterion variable among two samples of pupils drawn at random from the same population and taught to read (a) in i.t.a. and (b) in traditional orthography. It is hypothesized that the beta weights for the phonological variables would be greater in the sample taught in i.t.a. than in the sample taught in t.o.; that the

of course, be tested. If a longitudinal investigation could be conducted, using the six different methods of teaching reading in comparable samples, it would also be possible to test the hypothesis that different methods of teaching reading result, at least initially, in different models or general working systems for attaining speed and power of reading. If this hypothesis is tenable, the next question is whether the differences are lasting or whether convergence of the different patterns of skills would tend to take place within defined periods of time (Singer, 1968).

Data suggest that not all teaching methods are equally appropriate for all children. Bond (1935) and Fendrick (1935), in a pair of coordinated studies, revealed some interaction between method of instruction and modality deficiencies. Children who had a visual handicap tended to learn better by a phonics method while children with auditory defects tended to learn better by a look-say method. Thus, although children in general can adapt to various methods of instruction, some children benefit more when methods are adapted to the hierarchical mode and sequence in which they can learn best.

HIERARCHY OF ACQUISITION OF READING BEHAVIOR

As the learner progresses in reading, he builds up a hierarchical organization of subsystems (Holmes, 1965; Singer, (1965a). Gagné's (1965) hierarchical model for decoding can be defined as a logically organized input sequence based upon some laboratory evidence and the assumption that oral language development is a necessary prerequisite for learning to read.*

Gagné's initial-input hierarchy terminates with words that conform to regular pronunciation. The hierarchy starts at the lowest level with reproduction of single letter sounds, an ability that is basic and underlies two branches. One branch involves speaking and learning orally presented single syllables and, later, multisyllabic words. The other branch

---

beta weights for the morphological and lexical variables would be greater in the sample taught in t.o. than in the sample taught in i.t.a.; and that the beta weights for the syntactical variables would be insignificantly different in the two samples.

*Oral language development as a necessary prerequisite for learning to read may be an unnecessary assumption. Reed (1970) points out that deaf children can learn to relate at least some graphic configurations to linguistic forms <u>before</u> they have learned to associate oral expression with these same linguistic forms. See Gibson, Shurcliff, and Yonas' study on deaf subjects (1970).

is a hierarchy for symbol identification. It consists (a) of learning to respond to printed letters by sound; (b) of pronunciation of single vowels or consonants, dipthongs, and alternate phonemic values; (c) of blending two to three vowel- and consonant combinations or syllables; and (d) of pronunciation of regular spelling patterns with different phonemic values. At the syllable and again at this point, the two branches combine. In three more stages, the individual learns (a) to pronounce printed words composed of closed syllables, (b) to test cues to match oral reproduction with familiar oral vocabulary, and (c) to read words based on regular pronunciation rules.

Later stages of reading consist of learning additional rules for irregularly spelled words. Comprehension, constituting another domain, consists of a series of intellectual tasks, which subsume predicting sequences of thought, detecting irrelevant ideas, formulating the main idea, and inferring meanings of unfamiliar words from context. These components of comprehension, according to Gagné, are learned by "practicing reading with a variety of subject-matter content." With greater facility in reading, the reader achieves speed by making better predictions and by sampling stimuli rather than responding to each printed word. Higher-order rules pertain to longer units of discourse, such as paragraphs and chapters. All of the rules or principles are "typically learned" not by a deductive method, but by an inductive discovery method during the act of reading. For various types of reading, the reader must develop particular rules; for example, literary standards for reading literature critically.

The basic assumption in Gagné's hierarchical organization of decoding behavior is that for ease of learning at each stage there is a particular order of skills that must be acquired in a given sequence. Gagné believes that shortcuts in the hierarchy are accompanied by limitations in ability to generalize the acquired abilities. Learning of component parts of the hierarchy is consistent with his hierarchical order of learning in general, consisting at base of a conditioning type of learning of word sounds and ending with problem solving. Involved in this learning hierarchy are all the S-R and field theories of learning (Gagné, 1965).

Complementing Gagné's hierarchical organization of psycholinguistic components for decoding is an organization of the mental structures and processes involved in word recognition (Samuels, 1970, 1971). The process for developing and using this mental organization starts with a printed stimulus. Through discrimination learning, the individual selects cues and develops responses to them which are stored in long-term memory. Subsequently, selected cues go into short-term memory and are recognized through visual processes, perhaps in association with the auditory system. Next the cues enter

long-term memory and then are read for "hook-up" with available responses and integrated or blended with previous responses to cues. Response availability may be facilitated through control of context and associative connections between words. Linguistic variables also affect systems involved in learning to read new words, but Samuels does not specify the linguistic variables or the mental components or processes affected by them. Thus, when the reader has selected and recognized a cue, has the appropriate response available for pairing with the cue, has hooked up the cue with its response, and has blended it with previously paired cues and responses, he is able to recognize or say the word.

Encompassing Gagné's and Samuels' models, substrata-factor theory of reading (Holmes, 1960) postulates that underlying and supporting each component of reading (such as speed or power of reading) or underlying each factor (such as word recognition) or each system (such as decoding) is a functionally organized hierarchy of interwoven neurological subsystems, identified as terms in a branching sequence of linear regression equations (Davis, 1964). As an individual learns to read, he gradually develops interrelated subsystems and strategies for decoding, mediational processing, and encoding of responses to printed stimuli. As an individual's subsystems improve in variety, magnitude, and intercommunicability as a result of maturation, learning, and experience in mobilizing subsystems for responding to printed stimuli, he becomes more flexible in organizing and reorganizing his subsystems according to his purposes and the demands of the stimulus tasks.

The developmental hypothesis of the theory has been confirmed at the intermediate-grade levels (Singer, 1965a). Although evidence at the primary-grade levels appears to be consistent with the hypothesis that different input sequences of instruction will have differential effects upon the acquisition of a hierarchical structure and its relationships for reading, the hypothesis still needs to be tested at this level.

Another question that needs to be answered is whether the various input sequences eventually result in the same or in quantitatively or qualitatively different subsystems for reading, or both. It should also be possible to determine statistically whether one input, as compared with another, provides an "initial kick" (Holmes & Singer, 1964) that results in a cumulative advantage in reading performance. Further investigation is also needed to determine whether children with different cognitive styles (Tyler, 1969) or ways of perceiving stimuli benefit more from one input strategy than another.

These three sequential models can be conceptually integrated into one stimulus-organismic-response model.

Gagné's model emphasizes a logically determined input hierarchy; Samuels' implicit model stresses the organismic components and processes involved in learning and decoding print to speech. Substrata-factor theory, utilizing a multiple-regression procedure for testing hypotheses and for constructing performance models, emphasizes the hierarchical subsystems that can be mobilized in response to the purpose of the reader and the demands of the task stimuli. This integration can be empirically tested through a longitudinal investigation at the primary grades by using Gagné's model for determining an instructional input sequence and substrata analysis for empirically constructing the resulting performance model for decoding print to speech. Correspondence between the input sequence and the performance model would tend to confirm the integration of the models.*

SUMMARY AND CONCLUSIONS

Beginning reading instruction in the United States varies along a historically related methodological continuum from a unit of instructional emphasis that varied in a surprisingly systematic way from the smallest to the largest stimulus; from the letter to the entire sentence or paragraph. The methods along this continuum can be categorized into one or the other of the two major classes of learning theories, stimulus-response or cognitive and field-theory models.

Methodological and instructional models have tended, at least in the initial stages of learning to read, to result in quantitative and qualitative differences in reading performance. Laboratory investigations of learning to read have also discovered variations in performance as a consequence of instructional procedures (such as speed of initial learning) with little, or even negative, transfer to a slower rate of learning to recognize printed words but with more positive transfer.

Major components of learning to read have been identified as letter discrimination, decoding to speech, and shifting of perceptual units from phoneme-grapheme relationships to higher-order units or patterns that also have an invariant relationship to speech. However, evidence for learning these components, based on laboratory investigations in paired-associate learning paradigms, is susceptible to modification when the components to be learned are put into sentence

---

*Other integrations, such as Spache's input sequence based upon Guilford's structure-of-intellect model and Barrett's comprehension model (based upon the taxonomy of educational objectives), could be similarly tested (Singer, 1970b).

context in which syntactic and semantic constraints and redundancies inherent within normal language can function.

Linguistically derived models for the initial stage of reading instruction also vary in emphasis along a continuum. Learning to relate graphic and speech representations of linguistic forms in isolation constitutes one extreme of the continuum. At the other extreme, the child is taught to decode at first graphic representations of his <u>own</u> language, which necessarily involves graphophonological, syntactical, and semantic systems for transforming surface to deep structure, testing meaning, and if confirmed, encoding it for overt expression. Although the language competence of the beginning reader may be involved in instruction at both ends of the continuum, the transformational-generative grammar-determined model, which explicates the structures and processes underlying performance in reading, is more likely than models towards the other end of the continuum to provide conditions of instruction for activating the language competencies of the beginning reader and thus facilitating his reading.

As the learner progresses in reading acquisition, he builds up a hierarchical organization of subsystems. Three models were identified with this hierarchical reorganization and can be conceptually integrated into a stimulus-organismic-response model for learning to read.

Much more research and theorizing needs to be done at the learning-to-read stage before learning theories and strategies, linguistically-determined units and sequences of instruction, and psychological theories for explaining input, mediational processing, and output response systems can be integrated into a comprehensive theory of instruction. Such a theory would also have to encompass differences in cognitive or perceptual learning styles and decision-making, criteria for determining strategies for achieving various subgoals in teaching reading, such as a rapid rate of initial success with little transfer versus a slow rate of initial success with a maximum degree of transfer.

Steps towards a comprehensive theory of instruction for teaching reading have already been taken by some research workers, such as Goodman (1970), Coleman (1969), and Bormuth (1969). As theory or theories of instruction develop further, we will be closer to our ideal of adapting methods and materials to each individual.

REFERENCES

Agnew, D. C. The effect of varied amounts of phonetic training on primary reading. Durham, N. C.: Duke University, 1939.

Athey, I. J. Reading-personality patterns at the junior high school level. Unpublished doctoral dissertation, University of California, Berkeley, 1965.

Athey, I. J. Affective factors in reading. In H. Singer & R. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 98-123.

Athey, I. J., & Holmes, J. A. Reading success and personality characteristics in junior high school students. Berkeley: University of California Press, 1969.

Austin, M. C., & Morrison, C. The first R: The Harvard report on reading in the elementary schools. New York: Macmillan, 1963.

Biemiller, A. The development of the use of graphic and contextual information as children learn to read. Reading Research Quarterly, 1970, 6, 75-98.

Bishop, C. H. Transfer effects of word and letter training in reading. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 215-221.

Bloomfield, L. Linguistics and reading. Elementary English Review, 1942, 19, 23-30; 183-186.

Bond, G. L. The auditory and speech characteristics of poor readers. New York: Teachers College, Columbia University, 1935.

Bond, G. L., & Dykstra, R. The cooperative program in first-grade reading instruction. Reading Research Quarterly, 1967, 2, 5-142.

Bond, G. L., & Tinker, M. A. Reading difficulties: Their diagnosis and correction. (2nd ed.) New York: Appleton-Century-Croft, 1967.

Bormuth, J. R. Research on literal comprehension. Paper read at the Annual Convention of the International Reading Association, Kansas City, May, 1969.

Buswell, G. T. Fundamental reading habits: A study of their development. Chicago: University of Chicago Press, 1922.

Carroll, J. B. Language and thought. Englewood Cliffs, N. J.: Prentice-Hall, 1964.

Chall, J. Learning to read: The great debate. New York: McGraw-Hill, 1967.

Chomsky, N. Aspects of the theory of syntax. Cambridge, Mass.: M.I.T., 1965.

Chomsky, N. Phonology and reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. Pp. 3-18.

Coleman, E. B. Management plan for a national effort in reading. Paper presented at the meeting of the National Reading Conference, Atlanta, December, 1969.

Davis, F. R., Jr. The substrata-factor theory of reading: Human physiology as a factor in reading. In J. A. Figurel (Ed.), Improvement of reading through classroom practice. Newark, Del.: International Reading Assocation, 1964. Pp. 292-296.

Delacato, C. H. The treatment and prevention of reading problems. Springfield, Ill.: Charles C. Thomas, 1959.

Ellson, D. G., Barber, L., Engle, T. L., & Kempworth, L. Programmed tutoring: A teaching aid and a research tool. Reading Research Quarterly, 1965, 1, 77-127.

Fendrick, P. Visual characteristics of poor readers. New York: Teachers College, Columbia University, 1935.

Fries, C. C. Linguistics and reading. New York: Holt, Rinehart, & Winston, 1962.

Frostig, H., & Home, D. The Frostig program for the development of visual perception. Chicago: Follett, 1964.

Gagné, R. M. Conditions of learning. (2nd ed.) New York: Holt, Rinehart, & Winston, 1965.

Gates, A. I., Bond, G. L., & Russell, D. H. Methods of determining reading readiness. New York: Teachers College, Columbia University, Bureau of Publications, 1939.

Gibson, E. J. Learning to read. Science, 1965, 148, 1066-1072.

Gibson, E. J., Bishop, C. H., Schiff, W., & Smith, J. Comparison of meaningfulness and pronunciability as grouping principles in the perception and retention of verbal material. Journal of Experimental Psychology, 1964, 67, 173-182.

Gibson, E. J., Osser, H., & Pick, A. D. A study in the development of grapheme-phoneme correspondences. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 142-146.

Gibson, E. J., Shurcliff, A., & Yonas, A. Utilization of spelling patterns by deaf and hearing subjects. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970.

Gillooly, W. B. Influence of writing-system characteristics on learning to read. Paper presented at the meeting of the American Educational Research Association, New York, February, 1971.

Goodman, K. S. (Ed.) The psycholinguistic nature of the reading process. Detroit: Wayne State University, 1968.

Goodman, K. S. The reading process: Theory and practice. In R. Hodges (Chairman), Invitational Pre-conference on "What Do Teachers Need to Know about Language and Language Use," International Reading Association, May, 1970.

Hartley, R. N. Effects of list types and cues on the learning of word lists. Reading Research Quarterly, 1970, 6, 97-121.

Hildreth, G. H., Griffiths, N., & McGauvran, M. E. Manual for the Metropolitan Readiness Tests. New York: Harcourt, Brace, & World, 1965.

Hochberg, J., & Brooks, V. Reading as an intentional behavior. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 304-314.

Holmes, J. A. The substrata-factor theory of reading: Some new experimental evidence. In J. A. Figurel (Ed.), New frontiers in reading. Newark, Del.: International Reading Association, 1960. Pp. 115-121.

Holmes, J. A. Basic assumptions underlying the substrata-factor theory. Reading Research Quarterly, 1965, 1, 4-28.

Holmes, J. A. Toward the generalization of the substrata-factor theory to include a deterministic-nondeterministic learning theory. In G. B. Schick & M. May (Eds.), New frontiers in college-adult reading. Milwaukee, Wis.: National Reading Conference, 1966. Pp. 102-115.

Holmes, J. A., & Singer, H. Theoretical models and trends toward more basic research in reading. Review of Educational Research, 1964, 34, 127-155.

Jeffrey, W. E., & Samuels, S. J. The effect of method of reading training on initial reading and transfer. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 354-358.

Kephart, N. C. The slow learner in the classroom. Columbus, Ohio: Merrill, 1960.

Levin, H., & Watson, J. The learning of variable grapheme-to-phoneme correspondences: Variations in the initial consonant positions, A basic research program on reading. Ithaca, N. Y.: Cornell University, 1963.

Manolakes, G., Weltman, R., Scian, M. J., & Waldo, L. Try tasks 1, 2, and 3. New York: Noble & Noble, 1967.

Moore, O. K. In Helen Rowan, "Tis Time He Should Begin to Read." Carnegie Corporation of New York Quarterly, 1961, 9, 1-3.

Osgood, C. E. Method and theory in experimental psychology. New York: Oxford University Press, 1953.

Pick, A. D. Improvement of visual and tactual form discrimination. Journal of Experimental Psychology, 1965, 69, 311-339.

Reed, D. W. A theory of language, speech and writing. Elementary English, 1965, 42, 845-851.

Ruddell, R. B. The effect of the similarity of oral and written patterns of language structure on reading comprehension. Elementary English, 1965, 32, 403-410. (a)

Ruddell, R. B. The effect of four programs of reading instruction with varying emphasis on the regularity of grapheme-phoneme correspondences and the relation of language structure to meaning on achievement in first-grade reading. Berkeley: University of California, 1965. (b)

Ruddell, R. B. A longitudinal study of four programs of reading instruction varying in emphasis on regularity of grapheme-phoneme correspondences and language structure on reading achievement in grades two and three. Berkeley: University of California, 1968.

Ruddell, R. B. Psycholinguistic implications for a systems-of-communications model. In K. Goodman & J. T. Fleming (Eds.), Psycholinguistics and the teaching of reading. Newark, Del.: International Reading Association, 1969. Pp. 61-78.

Samuels, S. J. Attentional processes in reading: The effect of pictures on the acquisition of reading responses. Journal of Educational Psychology, 1967, 58, 337-342.

Samuels, S. J. Relationship between formal intralist similarity and the von Restorff effect. Journal of Educational Psychology, 1968, 59, 432-437.

Samuels, S. J. Modes of word recognition. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 23-37.

Samuels, S. J. A three-stage model of flashed words. In F. Greene (Ed.), Twentieth yearbook of the National Reading Conference. Milwaukee, Wis.: National Reading Conference, 1971, in press.

Samuels, S. J., & Jeffrey, W. D. Discriminability of words and letter cues used in learning to read. Journal of Educational Psychology, 1966, 57, 337-340.

Singer, H. Substrata-factor theory of reading: Theoretical design for teaching reading. In J. A. Figurel (Ed.), Challenge and experiment in reading. Newark, Del.: International Reading Association, 1962. Pp. 226-232.

Singer, H. Substrata-factor reorganization accompanying development of general reading ability at the elementary-school level. Final Report, Contract No. 2011, U.S. Office of Education, 1965. (a)

Singer, H. A theory of human learning for teaching reading: A discussion of Professor Arthur Staats's "Integrated Functional Learning Theory for Reading." In A. J. Kingston (Ed.), Use of theoretical models in research. Newark, Del.: International Reading Association, 1965. Pp. 68-73. (b)

Singer, H. Conceptualization in learning to read. In G. B. Schick & M. May (Eds.), New frontiers in college-adult reading. Milwaukee, Wis.: National Reading Conference, 1966. Pp. 116-132.

Singer, H. Stimulus models for teaching reading. In M. Clark & M. Maxwell (Eds.), Reading: Influences on progress. Edinburgh, Scotland: United Kingdom Reading Association, 1968. Pp. 112-119.

Singer, H. Theoretical models of reading. Journal of Communication, 1969, 19, 134-156.

Singer, H. Research that should have made a difference. Elementary English, 1970, 47, 27-34. (a)

Singer, H. Theoretical models of reading: Implications for teaching and research. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 147-182. (b)

Singer, H. Teaching word recognition skills. In M. A. Dawson (Ed.), Teaching word recognition skills. Newark, Del.: International Reading Association, 1971. Pp. 2-14.

Singer, H. William Gillooly's paper, "Influence of writing-system characteristics on learning to read." Paper presented at the meeting of the American Educational Research Association, New York, February, 1971.

Singer, H., Balow, I. H., & Dahms, P. A continuum of teaching strategies for developing reading readiness at the kindergarten level. In J. A. Figurel (Ed.), Forging ahead in reading. Newark, Del.: International Reading Association, 1968. Pp. 463-468.

Singer, H., & Beasley, S. Motivating a disabled reader. In Thirty-seventh yearbook of the Claremont College reading conference. California: Claremont College, 1970. Pp. 141-160.

Singer, H., & Ruddell, R. B. (Eds.) Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970.

Skailand, D. B. A comparison of four language units in teaching beginning reading. Unpublished doctoral dissertation, University of California, Berkeley, 1970.

Smith, N. B. American reading instruction. Newark, Del.: International Reading Association, 1965.

Staats, A. W. Integrated functional learning theory for reading. In A. J. Kingston (Ed.), Use of theoretical models in research. Newark, Del.: International Reading Association, 1965.

Staats, A. W. Learning, language, and cognition. New York: Holt, Rinehart, & Winston, 1968.

Staats, A. W., Brewer, B. A., & Gross, M. C. Learning and cognitive development: Representative samples, cumulative-hierarchical learning, and experimental longitudinal models. Monographs of the Society for Research in Child Development, 1970, 35-85.

Thorndike, E. L. The teacher's word book. New York: Bureau of Publications, Teachers College, Columbia University, 1921.

Thorndike, E. L. The teacher's word book of 20,000 words. New York: Bureau of Publications, Teachers College, Columbia University, 1931.

Thorndike, E. L., & Lorge, I. D. The teacher's word book of 30,000 words. New York: Bureau of Publications, Teachers College, Columbia University, 1944.

Tyler, F. T. Readiness. In R. L. Ebel (Ed.), Encyclopedia of educational research. (4th ed.) Toronto, Ontario: Macmillan, 1969. Pp. 1062-1068.

Williams, J. P. Successive vs. concurrent presentation of multiple grapheme-phoneme correspondences. Journal of Educational Psychology, 1968, 55, 309-314.

Williams, J. P. Reaction to modes of word recognition. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 38-46.

Williams, J. P., & Ackerman, M. Simultaneous and successive discrimination of similar letters. Journal of Educational Psychology, 1971, 62, 132-137.

Woodworth, R. S. Psychology. (Rev. ed.) New York: Holt, Rinehart, & Winston, 1929.

7-141

LEARNING TO READ: A REVIEW OF

THEORIES AND MODELS

Joanna P. Williams

University of Pennsylvania

Until very recently, there has not been a great deal of interest in the development of a comprehensive theory of reading. Rather, reference to theory and to formulations outside the province of the reading field itself--from psychology, for example--tended to be motivated by an attempt to improve instruction for the beginning reader. The emphasis on the unitary nature of the word, for example, was justified on the basis of principles of Gestalt psychology: that the whole was greater than the sum of its parts; and that people, especially children, could better handle the familiar and the concrete. Buttressing the theoretical position were data indicating that tachistoscopic recognition of a word was equal to that for a single letter and easier than that for a nonmeaningful combination of letters (e.g., Cattell, 1885).

Because the focus was clearly on implications for educational practice, it was not so important that "reading" in its entirety be analyzed and put together into one grand scheme. Instead, ideas, general or specific, or methodologies from other fields that looked promising might be borrowed for use in work in reading. More recently, simple operant-conditioning principles have been used to teach prereading skills and beginning reading, and, as an example from the field of linguistics, regular grapheme-phoneme correspondences have been emphasized in introductory reading material.

Our focus seems to have changed. Clearly, our ultimate goal is still the improvement of reading instruction. However, what we are really working toward at present is the development of a model of reading geared more nearly to the generation of research hypotheses. In fact, we are quickly proceeding to the point where our theoretical formulations--and empirical findings--may become too refined and sophisticated to be of great use in helping to determine instructional procedures (Williams, 1970). Perhaps I am being too sanguine about the progress we are likely to make in theory development --or too pessimistic about how effectively our work will be translated for use in the classroom, but I do feel that we must keep at least part of our attention on the goal of how our models can be applied to instructional problems.

I shall describe briefly several recent models which represent a wide variety of approaches. I have categorized them as follows: taxonomic, psychometric, psychological, linguistic, and transactional. My discussion will focus primarily on the psychological and linguistic models, most of which might be included under the general heading of 'psycholinguistic.' Obviously, there is a great deal of overlap, and some approaches are more difficult to categorize than others.

Practically all of the recent work in model building has focused on the cognitive aspects of learning to read, and my review will reflect this current emphasis. Up to this point, there has been little attempt to incorporate affective factors into reading models. Athey and Holmes's monograph (1969) is an excellent review of this area.

TAXONOMIC MODELS

Gray

We are well past the stage of purely descriptive model building. Those interested in this earlier approach should review William Gray's model (1960), which is unusual in its comprehensiveness. Essentially, the model categorizes the skills underlying reading into four classes: word perception (including pronunciation and meaning); comprehension; reaction to, and evaluation of, ideas of the author; and assimilation of what is read, through fusion of old ideas and information obtained through reading.

In an elaboration of Gray's theory, Robinson (1966) added a fifth category, rate of reading, which is flexibly adapted to varying reading purposes. Robinson also stressed the importance of differentiating reading skills (her primary focus) from processes and from instructional procedures. This work has been of some value as a "teaching model."

PSYCHOMETRIC MODELS

Holmes

One very influential approach of the psychometric variety is that of Holmes (1953). His substrata-factor theory has been elaborated and refined continually since its inception by himself and others, notably Singer (1970). Essentially, in substrata analysis, a variety of tests is chosen, which assess variables that on the basis of theory or past research seem to contribute to the variance in reading comprehension. The factors that turn out to account for most of the variance in the criterion are determined, and then these factors are again analyzed, leading to a set of "sub-variables,"

i.e., those factors that make a significant contribution to the variance of each of the first-order factors. The goal is to determine the nature of the combination of the hierarchically organized subsystems that form a working system for attaining speed and power of reading.

It has been pointed out that Holmes's system does not constitute a "theory" in the true sense of the word, primarily on the grounds that it is nonpredictive (Clymer, 1968; Sparks & Mitzel, 1966).

PSYCHOLOGICAL MODELS

The first sallies into reading by psychologists were, as might be expected, fairly simple. Traditional learning approaches, especially operant conditioning and rote verbal learning, represent the early psychological formulations.

Behavioral

Skinner

Skinner did not have a great deal to say about reading. In Verbal Behavior (Skinner, 1957), textual behavior is described as vocal verbal responses under the control of nonauditory verbal stimuli. Skinner mentions automatic reinforcement of reading activity; that is, reinforcement based on the reader's interest. He talks about the question of the appropriate unit in instruction. He discusses the difference between the beginner, for whom textual behavior is predominant, and the skilled reader, whose behavior in response to written verbal stimuli may be "nontextual," i.e., he responds directly as he would to any feature of the environment. (In more common parlance, this refers essentially to the dropping out of the decoding phase.) Skinner's formulation does not stress the nature of the written language as a code; he compares textual behavior with echoic behavior and mimicry. "The automatic reinforcement of reading an 'interesting' text, however, has merely the effect of increasing the probability of occurrence of such behavior; it does not differentially reinforce correct forms at the phonetic level." A more comprehensive analysis of reading that fits into this framework was done by Hively (1966).

Staats

There is difficulty at times in trying to draw a sharp distinction between, say, a behaviorist and a cognitivist formulation. This is the case partly because there have been modifications in the approach of certain theorists. Staats

is a prime example. We tend to think of him as a leading proponent of the behaviorist point of view. Indeed, his earliest work in reading was firmly within a strict operant-condition tradition. Reading acquisition, according to Staats et al. (1962), is "discrimination training where certain verbal responses are reinforced in the presence of certain visual stimuli." The emphasis on the development of a system of reinforcers (tokens which could be exchanged for trinkets and edibles), a discrimination-learning apparatus, and the presentation of cumulative records indicating number of textual responses acquired (the particular textual responses not specified) are all within the operant learning tradition. The reading materials he used were simply single letters or consonant-vowel combinations, chosen to reduce response variation. There was little interest in, or even acknowledgment of, reading as a language process.

However, Staats's recent work, while clearly a continuation of his early experiments, has a rather different formulation. His 1968 book and the monograph by Staats, Brewer, and Gross (1970) perhaps can be seen as evidence of a growing rapprochement among different theoretical schools. Staats still sees elementary reading as a process of instrumental discrimination, and he feels that traditional learning principles and experimental techniques, using reinforcement contingencies, are appropriate for the acquisition of reading and for the study of the processes involved. However, he describes reading as a complex, cognitive skill, many of whose components must be developed on the basis of already-learned more basic skills (including language repertoires); i.e., it is an instance of cumulative-hierarchical learning. Moreover, since the process develops slowly, methods involving long-term investigation are needed--that is, detailed study of an experimental-naturalistic nature.

In his experiments, Staats has demonstrated that certain basic units can be acquired through discrimination training. Training was given on a series of six consonant-vowel combinations to a fairly high criterion, followed by training to criterion on the same consonants combined with four additional vowel sounds. The generality of the learning was tested in the following way: two new vowel sounds were learned, and then these new vowels were combined with the consonants. On the first presentation of these novel combinations, the subject made only two errors, indicating that concept formation had taken place. Again, subjects learned CVC items in word-families (<u>cad</u>, <u>mad</u>, <u>pad</u>, etc.), and then were tested to see whether or not they had actively learned "reading units": after training on several syllable endings, a new syllable ending was introduced (e.g., <u>ab</u>). Testing consisted of new combinations of the initial letters from original training syllables, plus the <u>ab</u> ending. Staats suggests that this experiment shows how the production of novel combinations

of responses can occur without specific training. This answers one of the linguists' main criticisms of S-R theory. He also insists that cognitive development can be based on elementary learning principles. Additional skills are added to basic repertoires in a cumulative-hierarchical fashion, acquired by the same elementary learning principles.

Gagné

Another approach with a distinctively "learning" flavor is that of Gagné (1970). According to Gagné, there are eight distinct types of learning, ranging from signal learning to problem solving. Each is clearly distinguishable from every other, for it begins with a different state of the organism and ends with a different capability of performance. The eight learning types form a hierarchy, and the prerequisite for almost any one type is that learning of the next lowest type already be established.

Gagné's interest in planning sequences of instruction involves examining the learning structure of various content areas. These are broken down into smaller units of student competencies. His sequences are not "developmental," for people of all ages learn simple kinds of learning. Rather, increasingly complex forms of learning build on the simpler forms, no matter what the age of the subject.

Gagné has presented a learning hierarchy for the early stages of reading, the goal of which is decoding; specifically, mastery of the pronunciation rules for regularly spelled words. One important part of the behavior is the testing of "trial" pronunciations against familiar syllable sounds ("tion," "ity," etc.). The most basic ability required is that of reproducing single-letter sounds. Built on that is the identifying of single letters by their sounds, and built on that, pronouncing consonant and vowel combinations. Oral reproduction of syllables and syllable strings are skills subordinate to pronouncing printed words, and so they, too, are included in the hierarchy.

Later stages of reading would include the mastery of the rules for irregularities in the pronunciation of printed words, and, following that, a variety of structures involving comprehension. Gagné did not attempt to develop the learning hierarchy for decoding as more than a demonstration of how topics of school instruction are organized hierarchically, involving prerequisite learnings that grow progressively simpler, as one works down from rules to S-R connections. In learning to read, acquisition of word sounds and the mastery of verbal concepts are basic, and if learning at the higher levels is to occur with facility, attention must be paid to these fundamental prerequisites.

Cognitive

Gibson

Wherever on the continuum between "behavioral" and "cognitive" you choose to place Staats or Gagné, there is no questioning the label "cognitive" for the Cornell group's approach. Eleanor Gibson, Harry Levin and others at Cornell provided the impetus for Project Literacy and for much of the theory-based work on the psychology of reading that has resulted over the past few years.

As presented by Gibson (1970), the theory is comprehensive and well elaborated. It is divided into "phases." In the first phase, skills that are fundamental to learning to read are developed; namely, speech and the "graphic act." Since, for the normal child, written material is a second-order symbol system that decodes to speech, some competence in hearing and speaking must come first. Three aspects of language are important: the phonological, the semantic, and the syntactic systems. The child must be able to extract the information from each of these aspects of language. The child clearly must acquire a knowledge of the phonological rule system. He must also develop a basic conceptual system, including relations (same-different). He must also have some fundamental knowledge of syntax and morphology. The fundamental "graphic act" is scribbling, and the reinforcement for this activity comes from the opportunity to see the marks just made. The child develops awareness of graphic features, such as continuity, intersections, etc. He differentiates "writing" and "drawing," and then must differentiate the alphabet letters. This ability to differentiate two-dimensional forms increases with age.

Gibson states that the differentiation is done on the basis of a set of distinctive features. Gibson, Schapiro, and Yonas (1968), have outlined a set of distinctive features for upper-case Roman capitals, such that each letter is described uniquely in terms of the presence or absence of each feature. Learning the distinctive features and shapes of the letters might be called "content learning." Perceptual development also includes the development of active strategies, such as comparison and systematic scanning. Both the content and the strategies are motivated by a desire to reduce uncertainty, to give structure to the world, and it is this that reinforces perceptual development.

While Gibson acknowledges that a child must learn to identify the letters of the alphabet, i.e., give each letter its name, she sees this as an arbitrary and difficult task because it is one of rote memory and is, therefore, not intrinsically reinforcing. Is decoding (that is, mapping written text to speech sounds) also a matter of paired-associate learning? No, because there is no one-to-one

correspondence between sound and orthography. Gibson cites research by Cattell (1885) and Kolers (1966) indicating that people do not read letter by letter, and mentions Liberman's finding (Liberman et al., 1957) that a single phoneme is not perceived as such from instance to instance unless there is additional context. Gibson recommends that training in correspondences be done within a rule-oriented framework, so that children will be able to induce conceptual invariants from a wide variety of examples.

Gibson speculates about the role of articulation in learning to decode. Perhaps pronouncing, aloud or subvocally, is essential in beginning stages of reading. She is skeptical about Bever and Bower's (1966) suggestion that children might be trained to skip any auditory stage in the process of going from reading directly to meaning.

Analysis of the internal structure--the location of component correspondences--seems to be necessary for decoding new words. Bishop (1964) trained college sophomores on Arabic words either by a whole-word method or a component-letter method (i.e., presenting letters with their phonemic values). In the letter-sound group, transfer to new combinations of the already presented letter-sound correspondences was much greater; moreover, all of the transfer that was shown by the whole-word training group was due to a few subjects who had induced the correspondences by themselves. Jeffrey and Samuels' (1967) study with beginning readers resulted in similar findings.

The third and last phase is one of learning rules of unit formation. As the child becomes more skilled, he will use the structural principles to organize the information available and will be able to read in larger, more efficient units. Gibson has noted the following types of structural principles in written text: (a) correspondence rules between the phonological system and the graphological system; (b) rules of orthography, written consideration of sound; (c) grammatical constraints; (d) meaning, which provides context and expectancies about what is to come.

Gibson, Osser, Pick, and Hammond (1962) found that pseudo words that followed correspondence rules were more easily recognized tachistoscopically than were "unpronounceable" pseudo words; i.e., those that did not follow the rules. Third- and fourth-graders read the same stimuli aloud, and they took longer to read the less pronounceable ones (Biemiller & Levin, 1968). Other developmental studies (Gibson, Osser, & Pick, 1963) indicated that first-graders have already begun to generalize a few very simple spelling-to-sound correspondences. Much of this rule induction, especially beyond the first-grade level, is accomplished by the child with no explicit training. That Gibson's pseudo words differed

specifically in terms of spelling-pattern-sound correspondences is unclear, since congenitally deaf readers also responded more quickly to the "pronounceable" items (Gibson, Shurcliff, & Yonas, 1970). This finding indicated that there must be rules of orthography, "a kind of grammar for letter sequences that generates permissible combinations without regard to sound."

There is also the higher-order rule structure inherent in language in its morphological and syntactical aspects. Gibson has not concentrated much of her own research on these issues; she cites Levin's work. Working with the eye-voice span technique, Levin has demonstrated that the more structured the written text, the longer the span. It is longer for a sentence than for a random string of words (Levin & Kaplan, 1970); it is longer for right-embedded sentences, which are more highly constrained than left-embedded sentences (Levin et al., 1970). Developmental studies indicate that the effects of structure increase with age (Levin & Turner, 1966). These experiments are interpreted to demonstrate that the reader--at least the skilled reader--is sensitive to regularities in language structure, and that text is divided into higher-order units. Gibson points out that the effects may not be due to grammatical structure, per se, but rather to the meaning of the sentence. Since the syntactic and semantic systems are in fact not independent (Fodor & Garrett, 1967), it is impossible to answer this question.

In another study, Gibson and Guinet (see Gibson, 1970), using a tachistoscopic recognition technique, found that inflectional endings were read with fewer errors than non-inflectional endings on words of equivalent length, and the tendency increased from third to fifth grade. This suggests that there are finer, within-word cues to syntax that are processed as unitary word features.

In summary, Gibson's work is aimed at discovering the unit-forming principles in reading activity, and, when they are determined, the training methods that will promote effective strategies of perceptual search and detection of structure.

Elkind

An approach heavily oriented toward Piagetian theory has been offered by Elkind and, as such, it provides a sharp contrast to the behavioral models. Elkind concentrates primarily on the perceptual aspects of reading acquisition. His approach is based on the assumption that there are well-differentiated stages of development, and that the learning process or processes manifested by a child depend on his developmental level. It is first necessary to diagnose the level and

then to determine what processes are associated with that level (Elkind et al., 1965).

One of the first things a child must learn is that printed text is a representation, like speech, and that the markings on the printed page are arbitrary signs. This awareness develops according to the same principles as does the awareness of the arbitrariness of signs in general. The perceptual processes that account for this development are fundamental to an understanding of the development of reading in general.

Elkind denies the importance of discrimination and association as aspects of perceptual growth. Rather, the processes involved in perceptual growth are concerned with the basic development of decentration. That is, the young child's perception is centered in the sense that it is determined by the dominant aspects of the visual field--continuity, proximity, closure, etc. With age, perception becomes increasingly decentered; that is, freed from the domination of these field effects.

Elkind sees all of the perceptual processes as embodying logic. These processes include (a) perceptual reorganization (the ability to rearrange mentally a stimulus array without acting physically on it); (b) perceptual schematization (the ability to organize parts and wholes so that they retain their unique identities without losing their independence); and (c) perceptual exploration (the ability to scan systematically an array or a figure so that all its features are noted).

Because of the highly irregular nature of sound-spelling correspondence in English, the child must perform logical multiplications (schematizations) on the perceptual plane; this he is not able to do when he is very young. (This is the reason why Pitman's i/t/a is effective--it eliminates the need for these complex perceptual activities.) Clearly, the same perceptual activities are also important at later stages of reading acquisition. Rapid reading, for example, requires the ability to explore and anticipate words and sentences. Understanding grammatical structure also requires perceptual exploration and other processes.

Elkind and Deblinger (1969) gave inner-city children fairly extensive training on a variety of nonverbal perceptual exercises (three one-half-hour sessions per week for 15 weeks). The exercises included simple series, scrambled words, coding, etc. The subjects made significant improvement, compared with a control group trained on the Bank Street Readers, on word form, word recognition, and word association. There were no differences in comprehension. Interestingly, the control group did better on a "meaning-of-opposites" test. Thus, training in perceptual activities is effective.

Elkind (1967) has criticized look-say instruction on the ground that it inhibits the development of a true whole-part schematization, since it provides no training on analyzing parts of words. Most of his work, however, is focused on remedial-teaching methods. For Elkind, perceptual activities are internalized actions, which become internalized only after they have been mastered and perfected on the sensori-motor plane. Thus a variety of sensori-motor methods is recommended.

Information Processing

Venezky and Calfee

Venezky and Calfee (1970) present a model for skilled reading that falls clearly within an information-processing framework. Visual scanning, the first of several postulated processes, is directed by (a) general knowledge of the reader (stored in the integrated knowledge store), and (b) immediate knowledge from the material being read (stored in the temporary knowledge store). There are two types of immediate knowledge: what is deduced from the material, and thus creates expectancies; and what is obtained from what the eye is at that point processing. There are two (simultaneously-operating) forms of processing: syntactic-semantic integration of what has just been scanned, and forward scanning. The forward scanning is directed at the task of locating the largest manageable unit, the largest unit that can be chunked rapidly. The reader notes punctuation, for example, or phrase boundaries. When this unit is identified, forward scanning continues, and the information in the unit already identified is then integrated; i.e., related to what has previously been stored. A word is identified via search of the associative word store, which contains frequently encountered words and word parts, and of the low frequency store (larger and less well-organized). Using partial information and expectancies, matches are attempted. If there is a failure, more scanning is necessary. The good reader scans well, that is, he maintains a good balance between the two processes of integration and forward scanning, which must adapt to changes in the type of reading material and in the reader's purpose. Venezky and Calfee recommend that research be focused on task variables--studies of perception, memory, and strategy. Sternberg's (1969) and Neisser's (1967) search paradigms are suggested as the basis for relevant experiments.

In terms of this model, the nonreading six-year-old would have an empty letter store, no visual patterns in either word store, plus some knowledge of language and the real world. Input to the model would be, first, letter pairs, then words, and so forth. There is no distinction between integration and forward scanning in early stages of learning to read. Venezky and Calfee note, however, that important developmental changes

in abilities may complicate the issue, and they pose some general questions about the actual nature of the relevant cognitive processes and their acquisition.

Calfee, Chapman, and Venezky (1971) focus specifically on the acquisition of early stages in reading, and here their approach is rather different. The model's output is decoding, not comprehension. Research is designed to assess children's abilities in the several independent, component cognitive skills, which are seen as very specific abilities such as detecting differences in visual forms, determining whether two words rhyme, etc. In their heuristic model there are visual analytical processes (e.g., how a child recognizes and orders letters) and acoustic-phonetic analytical processes (e.g., how the child comes to perceive segmentation in spoken features). After the visual and the acoustic-phonetic elements are differentiated, they must be associated (correspondence learning). This may not be simple associative learning because, among other things, the associations are variable and they must be acquired in context.

The authors have developed a Basic Skills Test, consisting of a large set of subtests related primarily to the three primary areas of the acquisition model described above. These subtests were designed to sample the skill in a variety of different contexts. An attempt is made to identify the underlying psychological processes involved in the ability. Five areas of cognitive functioning are tested: matching of visual forms; auditory-phonetic identification; letter-sound association; vocabulary knowledge; and, general achievement. Preliminary results indicate that skill components, if narrowly defined, are quite independent. Performance on auditory matching and segmentation and on correspondence-learning tests was poor. Visual-perception skills were reasonably good but cognitive abilities, i.e., sequencing and memory for visual forms, were not good.

Roberts and Lunzer

A comprehensive statement of the information-processing point of view appears in Roberts and Lunzer (1968). They point out that language has a dual character: it is representational and communicates meaning; and, it is also behavior, a complex of skills. In addition, it is comprised of a set of symbols which are interrelated in complex ways. There are units of different sizes, and arrangements of these units comprise the grammar. Thus linguistic behavior involves concurrent activity at three levels: representational (semantic), grammatical, and perceptuo-motor (phonological). The establishment of reading skill depends on the acquisition of a high level of automatization at all three levels in relation to the interpretation of the written text. Reading is done in order

to obtain information, or, in other words, to reduce uncertainty. Information also has the effect of generating new uncertainty, so there is a cycle of uncertainty-information--new uncertainty.

Roberts and Lunzer present a complex schematic representation of processes involved in reading, stressing their hierarchical and sequential relations. The initiation of reading activity is due to motivational antecedents which are extraneous to the skill itself. The remaining elements represent decision processes or strategies, perceptuo-motor mechanisms, and active memory states or processes.

Two lowest levels of regulation are common to all behavioral organization and are not specific to reading: on the effector side, the control of effectors (head and eye movements, e.g.); and on the receptor side, a comparator system that determines a heightened sensitivity to a specific range of patterned output. Then there are five additional levels that are specific to reading. The mechanisms at all these levels are "strategies"; i.e., they regulate perceptuo-motor behavior by progressive definition of effector behavior and progressive restrictions of perceptual sensitivity. Levels are: paragraph, phrase, word, letter string, and letter. The levels are hierarchical in that higher-order strategies and mechanisms, when they operate, deactivate the lower-order ones.

In very careful reading, the subject may vocalize or at least identify each word, but he does scan ahead, and he perceives only as much as necessary to ensure correct reproduction of the text. Since the constraints derive from several levels of linguistic function, the actual perception of words cannot be divorced from the hierarchical structure of language itself. Letter strings, words, etc., are stored in immediate memory until their sense is revealed; then their sense is stored, etc.

When learning to read, the child has no "cue combination" corresponding to whole words in the comparator system--he must build these up. Of the many component skills that must be built up, some are independent, but some depend on the prior acquisition of others. Learning to read starts with the identification of the sound values of letters and of the relation between the written and spoken sequences. Within a year, these skills are automatized, but they are difficult skills for the beginner and they need careful analysis and study. Roberts and Lunzer argue that most of the component skills can and should be taught independently of the reading of text. Text reading will serve the function of practice and consolidation as well as providing goal activity for the part-lessons.

Smith

Smith (1971) has provided a very well-elaborated version of the information-processing point of view. Like other theorists working within this framework, he concentrates on a description of the skilled reader. Smith's feature-analytic model proposes that letter identification, word identification, and the comprehension of meaning are three distinct tasks that can be performed independently on the same visual information. The identification of a single letter is achieved as a result of testing a sufficient number of features (elements of the visual configuration; cf. Gibson's distinctive features) so that alternative responses are eliminated and uncertainty is reduced. Following Neisser (1967), Smith suggests that word identification is not necessarily based on prior letter identification. Rather, distinctive features directly provide the basis for word identification. In fact, according to this model, fewer visual features are required to discriminate a letter within a word than to discriminate a letter in isolation. By the same token, word identification can take place when there is insufficient information for identifying any of the individual letters; word-feature lists include information about location of feature.

Smith extends this type of analysis further. Comprehension of meaning, he says, is based on the same kind of feature analysis. The skilled reader uses information from the visual configuration plus information from context (e.g., he has knowledge of semantic and syntactic constraints--see Smith & Holmes, 1971). Comprehension of meaning thus requires less information than does word identification and, consequently, it precedes word identification in normal skilled reading.

A contribution of considerable value is Smith's analysis of how the information-processing capacities of the novice reader are taxed to a much greater extent than are those of the mature reader. The beginner cannot often identify words and meanings directly. Instead, mediated identification is required. Mediated word identification involves mapping the word onto its sound pattern, which is then used as the basis for the identification of the word. (Phonics rules are taught in order to maximize this translation from visual configuration to acoustic configuration.)

Similarly, in mediated meaning identification, word identification must occur so that there is a basis for comprehension. These mechanisms are disruptive because they overload the visual information-processing and memory systems. The beginner must learn to overcome these restrictions by utilizing the redundancies in written language (feature redundancy in individual letters; orthographic redundancy--cf. Gibson's spelling patterns; and redundancy across sequences of

words--syntactic and semantic constraints). Until he accomplishes this task, the novice must rely more heavily on the visual information that he picks up and, therefore, he will read more slowly and with less comprehension than he will after he has learned to use the redundancies.

The beginning reader has all the skills required for learning to read, including such abilities as making comparisons, establishing categories and rules, and formulating and testing hypotheses. Good instruction consists of providing the child with feedback as he tests his hypotheses of what the distinctive features might be and what categories are to be used for letter and word identification. On this basis he will develop the appropriate rules for himself.

LINGUISTIC MODELS

If there is one general limitation in the models discussed up to this point, it is that they under-emphasize the structure of language. Clearly, they note the fact that reading is a language process. And in practically all of the models, stress is placed on determining the nature of the units--determined at least partially by the structure of the language--that are used by the reader. But their major contribution is, understandably, in terms of psychological variables.

Early Formulations

There are some approaches whose emphasis is just the opposite: their main concern is language and the implications of linguistic analysis for reading as one type of language. These models, of course, also have much to say about the nature of the psychological processes involved--and what they say about them is reasonably well in line with other theories.

The application of linguistic knowledge to reading was, until recently, fairly restricted. Bloomfield (1942) believed that the irregularities in correspondence between orthography and speech should not be presented to beginning readers, but that only regular correspondences should be presented. Fries (1963) was also concerned primarily with letter-sound relationships. Lefevre (1964), however, was among the first to point out the importance of syntactical cues, both intra-word, such as inflections, and inter-word, such as sentence structure. One of his main interests was in the cuing of intonation.

For a while, great emphasis was placed on the difficulty of reading English because of its irregular grapheme-phoneme correspondences. Levin and Watson (1963) argued that

a child should be trained on variable correspondences from the beginning, so that he could develop a proper "set for diversity." Williams' (1968) data led to a similar conclusion. This concern with irregularity has diminished, however, because of the work of Venezky and Weir (1966), who demonstrated that there is considerable regularity between English orthography and oral language if one looks beyond the direct grapheme-phoneme relationship. The relationship between print and sound must be described in two steps. First, there are rules deriving lexical forms from the graphic input, and, secondly, rules deriving the phonemic form from the lexical data. Chomsky and Halle (1968) also analyze the relationship in two levels, but for them these levels are the lexical and the phonetic. According to Chomsky and Halle, in fact, orthography is a nearly optimal representation of the lexical level of spoken English. (Stress, for example, which is not marked in orthography, is predictable from the lexical level.)

Transformational-Generative Grammar

Recent notions about language development, especially as it has been described by those who work within the transformational-grammar framework, have been of great interest to people working in reading. The rejection of the passive, receptive learner for one who is actively constructing his language (on the basis, it is sometimes argued, of innate knowledge of linguistic universals), the distinction between competence and performance, the analysis of grammatical structure--these and other ideas have helped to lay the foundation for reading models that have a strong linguistic orientation.

Goodman

Goodman (1970) has been influenced greatly by transformational-generative theory. He sees reading as a constructive process, involving active information-processing. The reader, knowledgeable about language, brings his total experience to the reading task. Reading is a psycholinguistic process, in which the reader decodes from the graphic stimulus not to speech, but directly into deep structure. In oral reading, he then encodes the meaning into speech. Since comprehension and communication are the goals of reading, the proficient reader may recode into speech that contains transformations in vocabulary and syntax with no modification in meaning. Three kinds of information are used simultaneously--graphic, syntactic, and semantic. As reading proficiency improves, the reader, who has more control over language structure, better conceptual skills, more experience, and better sampling strategies, uses fewer and fewer graphic cues. Goodman argues that one cannot fractionate the reading process

into component skills, either for research or for instruction, because the reader does not use all of the information available in the text. He uses only enough to predict a decodable language structure.

Goodman's research strategy is to look at "miscues" in oral reading. Miscues are occurrences of mismatches between the text and the reader's response; they are not errors, because some very good reading may involve miscues, where meaning, of course, is not disturbed. An analysis of the miscues will lead to an understanding of the reader's strategies, and, in fact, instruction should be designed to maximize these sampling and hypothesis-testing strategies, rather than trying to get the child to attend to more specific details of the text.

Other investigators (Clay, 1968; Weber, 1970) have also investigated errors in oral reading. In general, studies indicate that most readers, even beginners, depend heavily on syntactical constraints; i.e., many substitutions within the same form-class are made. Fewer miscues are interpreted as being due to misperception of the graphic stimuli themselves. Yetta Goodman's intensive study (1968) of six first-grade readers over the course of eleven months indicated uneven development and strong individual differences. In general, however, the more proficient children made "better" errors, i.e., they demonstrated more complex processing, and they showed more ability to correct their errors when they conflicted with their expectancies about meaningful language. Thus language does control reading to a large extent.

Goodman's model presumably operates both for the beginner and the proficient reader, but one must not assume that the processes are the same. The model is complex, and it can be broken down into several alternative submodels so that it would represent the beginning reader vs. the skilled, or it could account for differences in an individual reader that would occur as he read material of different levels of difficulty.

Ruddell

Reading is but one aspect of communication, and Ruddell has presented a model of communication that includes speech, writing, listening, and reading. Using a transformational grammar framework, language is seen to operate on several levels. First, there is the surface structure, consisting of the relationships between morphophonemes and morphographemes. The second level consists of all the structural and semantic readings that lead to processing language for interpretation. The third is the deep structure of language. The first level is important in considering the

decoding process; all three levels are relevant in determining comprehension.

For Ruddell, decoding (i.e., discovering the nature of the correlation between printed units and their oral counterparts) is one of the central tasks in early reading instruction. Ruddell notes that children have managed to pick up decoding skills from a variety of approaches, many of which stress quite different units. He speculates that there may be a relationship between the optimal unit for instruction and particular learner characteristics.

The comprehension process involves relational meaning, both at the surface structure level (e.g., how perceptual units correspond to sentence constituents as designated by the linguist) and at the deep structure level (transformations). In addition, lexical meaning, including the importance of context in determining semantic possibilities, is important. The model also takes into account an individual's interests, attitudes and values (affective mobilizers), and his cognitive strategies; i.e., how he builds and tests hypotheses, organizes data, etc. Flexibility, depending on specific purposes of the reader, is assumed.

As reading progresses, a child goes from learning the nature of the code of the writing system to learning to decode. As cognitive strategies develop, he should gain alternate ways of handling print besides decoding words. With greater proficiency, the reader may move directly to meaning, relying less and less on the morphophonemic system.

Ryan and Semmel

A very good statement of this general point of view was presented by Ryan and Semmel (1969). Their paper leans heavily on a transformational grammar framework and stresses the fact that the child must have some degree of knowledge of grammar in order to take advantage of the regularities that exist on an abstract level. They argue that the beginning reader has, and uses to some extent at least, abstract rules about language structure. He should be trained so that he can use what he knows about language even more effectively in his reading. This means that instruction should stress the conceptual aspects, for concentrating on perceptual aspects would lead to absolute identifications of letters and words, and this would interfere with mature reading strategies.

Unlike the models based on psychological theories, which seem to represent all points of view about the nature of learning and development, comprehensive models based on linguistic analysis seem to be founded solely on transformational-generative grammar.

TRANSACTIONAL MODELS

Rosenblatt

Rosenblatt (1969) studied adults' reactions as they read poems. For her, the quality of the experience that the reader is living through, under the stimulus of the text, is the goal of the reading. There is an active, two-way relationship between reader and text. The "transaction" terminology developed by Dewey and Bentley underscores the importance of both elements in a dynamic relationship. The active seeking-out of particular aspects of the text and the tentative interpretations and reinterpretations make this analysis closely related to the more typical cognitive point of view. However, Rosenblatt contrasts this aesthetic mode of reading with "instrumental" reading, or reading primarily for information to be used after the reading event, not for the experience during the actual reading.

It is interesting to speculate what implications the reading teacher might draw from this transactional theory. Goodman's recommendations that guessing strategies be promoted might need revision, at least in certain instances, in view of the fact that whatever the cues may be for "aesthetic" reading, they will certainly be subtle and complex. Substituting little for small may be of no importance in reading a set of directions, but in a poem it might be disastrous.

COMMENTS ON SOME INTERESTING ISSUES

After reviewing these theories, it seems to me that we have achieved a fairly good consensus as to an overall view of reading. I think it would be most profitable now not to emphasize further elaboration and formalization of these comprehensive models. Rather, I would like to see us turn our attention to certain limited areas and attempt to refine certain notions that at this point need sharpening. We need "partial" models that are specific, rigorous, and testable. Samuels' (1971) three-stage model of the recognition of flashed words provides an example. The output of the model is well specified, the processes are carefully described, and data in support of the model are presented.

As the theories are presented now, there are not too many well-defined questions that, if evaluated in the laboratory or in the classroom, would provide a critical test of any of the theories. The biggest and clearest distinction that has been made, of course, is that between reading as a passive process, with the graphic input cuing directly and automatically the already learned and therefore instantly meaningful speech code; and, on the other hand, reading as an active, cognitive skill, involving complex strategies of

information selection and processing. At this point, there is little serious consideration given to the first alternative. Even Thorndike, who saw learning as the automatic association of simple, independent stimulus-response bonds, declared, in a study (1917) in which he looked at mistakes made in paragraph-reading, that the comprehension of textbooks was "far above the level of merely passive or receptive work." (It is not surprising that during the years that behaviorism flourished, there was little work on skilled reading; it was considered so complex as to be unstudiable.) We are now past the point where, in talking about proficient reading, the active-passive distinction is worth belaboring.

Consideration of the distinction between the active and passive nature of reading is important, on the other hand, in attacking problems of acquisition. Here, I think, the new focus within psychology on cognition and the new analyses of language will lead to some genuinely new insights. The rejection of a simple associative learning model for orthography-sound correspondence learning reflects the acknowledgment that a great many tasks are more profitably evaluated as "active" processes. Even in simple paired-associate and serial learning, the subject shows evidence that he has organized and coded the material. Staats's emphasis on the concept-formation paradigm and Gibson's emphasis on induction of conceptual invariants reflect this point of view.

Our task of model building is complicated significantly by the fact that reading training is usually undertaken when the child is going through a period of development characterized by significant changes in his cognitive capacities. From varied evidence, such as the increasing ability with age to conceptualize (Vygotsky, 1962), the increasing ability to integrate information based on different sensory inputs (Birch & Lefford, 1967) and his own work on discrimination and reversal learning, White (1965) suggests that the years from five to seven may mark a crucial transition in quantity and quality of thinking.

Does in fact the child pass through developmental stages during which different learning processes and strategies are available to him? Elkind (1965), following Piaget, states explicitly that this is the case. If so, we must take these fundamental differences into account in our models of reading acquisition. Most theorists, however, have taken a different position. For Staats (1970), the results of early cognitive learning affect the quality and quantity of later learning, but the same processes operate at all ages. Gagné posits different kinds of learning at different stages of development of a complex cognitive skill, but the learning hierarchy will be based on the same simple kinds of learning and progress toward the more complex, no matter what the age of the learner. This issue is of course a very general one,

and different points of view will likely lead to important distinctions in model building and research in reading.

It is also important to use care and caution in drawing implications for educational practice, for conclusions are based too often on poor or irrelevant data or on over-generalizations from theoretical formulations. Let me give an example. It is likely that a view of speech as a primary language system, and writing as derived from speech, helped support the notion that skill in reading is fostered by auditory feedback and that comprehension is a function of the reader's auditory memory. These notions would argue for an emphasis on oral reading, with expectations that a child would understand what he was reading if he could decode it appropriately and listen to what he was saying.

The newer view, that both speech and writing are derived from the same abstract representation of language, may also lead people to jump to a conclusion without proper evaluation. They may focus on the virtues of silent reading. This could lead to discounting the value of oral reading, when it well may be that oral reading provides an important source of feedback and support for the beginner, and when it is certainly the case that oral reading is the best way of monitoring the child's progress.

The model builders are themselves seldom responsible for making unjustified extrapolations. However, it would be helpful if they were alert to such possibilities, so that wherever possible, they could provide guidelines for others to follow.

SUMMARY

1. Models at present focus on cognitive aspects of reading; little attempt has been made to incorporate affective aspects into the models.

2. Several different theoretical positions within psychology, representing a wide variety of points of view, have been used in the development of models of reading, whereas transformation-generative grammar is the only theory from linguistics that is represented in recent attempts at comprehensive model building.

3. There seems to be a rapprochement among theorists toward a view of reading as both a complex cognitive skill, the goal of which is obtaining information, and a complex language system.

4. Most models focus on the reading process _per se_. This is due in large part, of course, to the theorists'

specific interest in skilled reading. However, the emphasis on proficient reading is also a result of the opinion that in order to understand the acquisition process, we must first study the skill as it appears in final form.

5. Most models of the acquisition phase focus on decoding and its prerequisite abilities. The mechanisms involved in making correspondences between orthography and sound cannot, however, be characterized in terms of simple associative learning. Rather, basic knowledge of language is intimately involved, as well as the utilization of complex active perceptual and cognitive strategies.

REFERENCES

Athey, I. J., & Holmes, J. A. Reading success and personality characteristics in junior high school students. University of California Publications in Education, 1969, 18, 1-80.

Bever, T., & Bower, T. G. R. How to read without listening. Project Literacy Report No. 6, January, 1966.

Biemiller, A., & Levin, H. Words with digraph spelling patterns. In The Analysis of Reading Skill. Cornell University, Final Report to U.S. Office of Education, 1968.

Birch, H. G., & Lefford, A. Visual differentiation, intersensory integration, and voluntary motor control. Monographs of the Society for Research in Child Development, 1967, 32, 1-82.

Bishop, C. H. Transfer effects of word and letter training in reading. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 215-221.

Bloomfield, L. Linguistics and reading. Elementary English Review, 1942, 19, 125-130; 183-186.

Calfee, R., Chapman, R., & Venezky, R. How a child needs to think to learn to read. I. L. Gregg (Ed.), Cognition in learning and memory. New York: Wiley, 1971, in press.

Cattell, J. M. Ueber die zeit der erkennung und benennung von schriftzeichen bildern und farben. Philosophische Studien, 1885, 2, 635-650.

Chomsky, N., & Halle, M. Sound pattern of English. New York: Harper & Row, 1968.

Clay, M. M. A syntactic analysis of reading errors. Journal of Verbal Learning and Verbal Behavior, 1968, 7, 434-438.

Elkind, D. Piaget's theory of perceptual development: Its application to reading and special education. Journal of Special Education, 1967, 1, 357-361.

Elkind, D., & Deblinger, J. A. Perceptual training and reading achievement in disadvantaged children. Child Development, 1969, 40, 11-19.

Elkind, D., Horn, J., & Schneider, G. Modified word recognition, reading achievement and perception de-centralization. Journal of Genetic Psychology, 1965, 107, 235-251.

Fodor, J. A., & Gerrett, M. Some syntactic determinants of sentential complexity. Perception and Psychophysics, 1967, 2, 289-296.

Fries, C. C. Linguistics and reading. New York: Holt, Rinehart, & Winston, 1963.

Gagné, R. M. The conditions of learning. (2nd ed.) New York: Holt, Rinehart, & Winston, 1970.

Gibson, E. J. The ontogeny of reading. American Psychologist, 1970, 25, 136-143.

Gibson, E. J., Osser, H., & Pick, A. D. A study in the development of grapheme-phoneme correspondences. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 142-146.

Gibson, E. J., Pick, A., Osser, H., & Hammond, M. The role of grapheme-phoneme correspondence in the perception of words. American Journal of Psychology, 1962, 75, 554-570.

Gibson, E. J., Schapiro, F., & Yonas, A. Confusion matrices for graphic patterns obtained with a latency measure. In The analysis of reading skill: A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968.

Gibson, E. J., Shurcliff, A., & Yonas, A. Utilization of spelling patterns by deaf and hearing subjects. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970.

Goodman, K. S. Reading: A psycholinguistic guessing game. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 259-271.

Goodman, Y. M. A psycholinguistic description of observed oral reading phenomenon in selected young beginning readers. Dissertation Abstracts, 1968, 29, 60.

Gray, W. S. Reading and physiology and psychology of reading. In C. W. Harris (Ed.), Encyclopedia of Educational Research. New York: Macmillan, 1960.

Hively, W. A framework for the analysis of elementary reading behavior. American Educational Research Journal, 1966, 3, 89-103.

Holmes, J. A. The substrata-factor theory of reading. Berkeley: California Book Company, 1953.

Jeffrey, W. E., & Samuels, S. J. The effect of method of reading training on initial reading and transfer. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 354-358.

Kolers, P. A. Reading and talking bilingually. American Journal of Psychology, 1966, 79, 357-376.

Lefevre, C. Linguistics and the teaching of reading. New York: McGraw-Hill, 1964.

Levin, H., Grossman, J., Kaplan, E., & Yang, R. Constraints and the eye-voice span in right and left embedded sentences. Language and Speech, 1970, in press.

Levin, H., & Kaplan, E. L. Grammatical structure and reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970.

Levin, H., & Turner, E. A. Sentence structure and the eye-voice span. Project Literacy Reports, 1966, No. 7, 79-87.

Levin, H., & Watson, J. The learning variable grapheme-to-phoneme correspondences. (A basic research program on reading, Cooperative Research Project No. 639) Ithaca, N. Y.: Cornell University, 1963.

Liberman, A. M., Cooper, F. S., Shankweiler, D. P., & Studdert-Kennedy, M. Perception of the speech code. Psychological Review, 1967, 74, 431-461.

Neisser, U. Cognitive psychology. New York: Appleton-Century-Crofts, 1967.

Roberts, G. R., & Lunzer, E. A. Reading and learning to read. In E. A. Lunzer & J. F. Morris (Eds.), Development in human learning. New York: American Elsevier Publishing Company, 1968.

Robinson, H. M. The major aspects of reading. In H. A. Robinson (Ed.), Reading: Seventy-five years of progress. Chicago: University of Chicago Press, 1966. Pp. 22-32.

Rosenblatt, L. M. Towards a transactional theory of reading. Journal of Reading Behavior, 1969, 1, 31-49.

Ruddell, R. B. Language acquisition and the reading process. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 1-19.

Ryan, E. B., & Semmel, M. I. Reading as a constructive language process. Reading Research Quarterly, 1969, 4, 59-83.

Samuels, S. J. A three-stage model of flashed words. In F. Greene (Ed.), Twentieth Yearbook of the National Reading Conference, 1971, in press.

Singer, H. A developmental model of speed of reading in grades three through six. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 198-218.

Skinner, B. F. Verbal behavior. New York: Appleton-Century-Crofts, 1957.

Smith, F. Understanding reading. New York: Holt, Rinehart, & Winston, 1971.

Smith, F., & Holmes, D. L. The independence of letter, word, and meaning identification in reading. Reading Research Quarterly, 1971, 6, 394-415.

Sparks, J. A., & Mitzel, H. E. A reaction to Holmes's basic assumptions underlying the substrata-factor theory. Reading Research Quarterly, 1966, 1, 137-145.

Staats, A. W. Learning, language, and cognition. New York: Holt, Rinehart, & Winston, 1968.

Staats, A. W., Brewer, B. A., & Gross, M. C. Learning and cognitive development: Representative samples, cumulative-hierarchical learning, and experimental-longitudinal models. Monographs of the Society for Research in Child Development, 1970, 35, 1-85.

Staats, A. W., Staats, C. K., Schutz, R. E., & Wolf, M. M. The conditioning of reading responses using "extrinsic" reinforcers. Journal of Experimental Analysis of Behavior, 1962, 5, 33-40.

Sternberg, S. Memory-scanning: Mental processes revealed by reaction-time experiments. American Scientist, 1969, 4, 421-457.

Thorndike, E. L. The psychology of thinking in the case of reading. Psychological Review, 1917, 24, 220-234.

Venezky, R. L., & Calfee, R. C. The reading competency model. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 273-291.

Venezky, R. L., & Weir, R. A study of selected spelling-to-sound correspondence patterns. Cooperative Research Project No. 3090, U.S. Office of Education, Stanford University, 1966.

Vygotsky, L. S. Thought and language. Cambridge, Mass.: M.I.T. Press, 1962.

Weber, R. M. First-graders' use of grammatical context in reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970.

White, S. H. Evidence for a hierarchical arrangement of learning processes. In L. P. Lipsitt & C. C. Spiker (Eds.), Advances in child development and behavior, 2. New York: Academic Press, 1965.

Williams, J. P. Successive vs. concurrent presentation of multiple grapheme-phoneme correspondences. Journal of Educational Psychology, 1968, 59, 309-314.

Williams, J. P. From basic research on reading to educational practice. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970.

SECTION 8

PAPERS ON READING PROCESS

PSYCHOMETRIC RESEARCH ON COMPREHENSION IN READING

Frederick B. Davis

University of Pennsylvania

INTRODUCTION

Psychometric research on reading has generally been restricted to small segments of the entire process. This paper considers only comprehension in reading; it does not deal with the mechanics of reading--the decoding process itself--although studies of the latter clearly indicate that decoding behaviors interact with comprehension. For organizational purposes, it takes up analyses of comprehension in reading under the following headings:

1. Broad Subjective Analyses;
2. Subjective Analyses Based on Specific Studies;
3. Regression Analyses, Including Uniqueness Analyses;
4. Principal-Component and Factor Analyses.

The first heading includes what are often termed "armchair" analyses that ordinarily take into account a wide range of experiential and experimental data and organize them according to some logical framework that satisfies the author. The second heading includes the great mass of experimental studies in reading that have been made during the past 70 years. Since most of these do not justify review, only a selection of the more important studies that have led to the formulation of partial models and models of comprehension have been included in this paper.*

---

*Research methodologists differ with respect to the definition of the word "model" in the sense in which it is used here. According to Webster's New International Dictionary, Third Edition, meaning 14a of the noun "model" is: "a description, a collection of statistical data, or an analogy used to help visualize, often in a simplified way, something that cannot be directly observed (as an atom)." For a more technical discussion, see Lachman (1960). See also Jacobson,

The third and fourth headings could properly be subsumed under the heading: Multivariate Analyses. The number of such studies that have been reported in the literature is much greater than the number included in this paper. In many instances, regression studies were used only for some specific problem of prediction and did not lead to salient conclusions about the nature of the processes of comprehension. Many multivariate studies have been based on so few cases (often as few as 20-50) that stable results could not possibly have been obtained. Hence, they do not qualify for discussion here.

BROAD SUBJECTIVE ANALYSES

During the present century, innumerable writers have presented analyses of the processes or skills thought to be involved in comprehension in reading. The characteristic that all of the analyses mentioned in this section have in common is a lack of association with any specific experimental data that provide empirical support for them. Nonetheless, all of them are based on wide-ranging experience in the teaching of reading and familiarity with experimental studies in the field.

One of the earliest of these armchair analyses of comprehension was published in 1919 by W. S. Gray in the Eighteenth Yearbook of the National Society for the Study of Education (Gray, 1919). Eight skills of comprehension were listed, as follows:

1. To read for the purpose of giving a coherent reproduction;
2. To determine the central thought or the most important idea of a selection;
3. To select a series of closely related points and their supporting details;
4. To secure information which will aid in the solution of a problem or in answering questions;
5. To gain a clear comprehension of the essential conditions of a problem;
6. To discover new problems in regard to a topic;

Stimart, and Wren (1971).

Gephart (1970) defines a model for purposes of research in reading as "a representation of a phenomenon which displays the identifiable structural elements of that phenomenon, the relationships among those elements, and the processes involved in the natural phenomenon [p. 38]." In this paper, models and partial models of comprehension in reading have been identified and described with Gephart's definition in mind.

7. To determine the lines of argument which support the point of view of the author;
8. To determine the validity of statements.

Among other subjective analyses of reading are those by Barrett (1968, pp. 19-23), Barton (1930), Berry (1931), Bloom et al. (1956), Cleland (1965), Gates (1935), Gray (1960), Kingston (1961), Robinson (1966), Smith (1960), Spache (1962, 1963), Strang (1938), and Yoakum (1928). Of these, the analysis of cognitive skills attributable to Bloom et al. (1956) is perhaps best known.

This armchair analysis of cognitive skills constitutes the Taxonomy of Educational Objectives. Handbook 1: Cognitive Domain. Its classification scheme was designed to cover the intended behavior of students--the ways in which individuals tend to act or think as the result of instruction in the cognitive area. These behaviors include:

1. remembering;
2. reasoning;
3. problem solving;
4. concept formation;
5. creative thinking.

It is obvious that these behaviors overlap, and the authors of the taxonomy recognized this fact. The more complex behaviors appear to include the simpler behaviors. Whether it is necessary for a reader to have the capability of performing certain simple behaviors before more complex behaviors can be demonstrated is not considered in the Taxonomy of Educational Objectives. This is a problem that has since been investigated by Chapman (1969), Gagné (1965, pp. 269-274), Hackett (1968), and others.

The Taxonomy of Educational Objectives covers most, though not all, of the skills included by Davis (1941) in his analysis of important skills of comprehension among mature readers. Davis' analysis was prepared to serve as an outline for the Cooperative Reading Comprehension Tests (Davis et al., 1940) and was put to immediate practical use for that purpose. To show the relationship between the two taxonomies, the category numbers used in Bloom's analysis have been placed in the right-hand column of Table 8 beside the corresponding skill in Davis' analysis. Skill VA (determining the writer's tone) of Davis' outline does not appear to be covered by Bloom's list. This skill was derived from Richards' analysis of comprehension of poetry (Richards, 1929) and refers to the relationship assumed by any writer with his audience. Skill VE in Davis' outline likewise does not appear to be directly covered in Bloom's list, though it could probably be fitted into his category 4.30.

The Taxonomy of Educational Objectives contains no evidence that the skills listed and illustrated do, in fact, exist as more than names and the writer knows of no exhaustive empirical studies on this matter. However, Knapp, Stoker, and Bashaw (1966) have discussed methodological problems in validating the taxonomy's list of skills and have made suggestions for solving these problems. Because of the marked degree of overlap shown in Table 8 between Bloom's list of skills, as applied to comprehension in reading, and Davis' earlier list (Davis, 1941), the latter's empirical studies of the extent to which his separately identifiable skills are characterized by the presence of unique nonchance variance can be applied to most of the skills listed by the former (Bloom et al., 1956). Davis' results are presented and discussed on pages 8-26 to 8-28 and 8-34 to 8-42.

A conceptual model of comprehension in reading was described by Kingston (1961). He defined comprehension as a process by which a reader recreates in his mind the thought content of the writer by interacting with what the latter produced. For this process to work effectively, Kingston postulated:

1. The writer must employ a medium of communication that is familiar to the reader. That is, the symbols used (words) and the ways in which these are combined (the syntactical structure) must be used by the writer and the reader in the same ways. This use is most likely to occur if they have had common experiences.
2. The reader must be capable of employing the same level of abstraction as the writer.
3. The reader must have appropriate motivation, mind set, and mechanical skills of word perception.

The need for empirical testing of conceptualizations of the reading process ("models") has been pointed out by Maccia (1966) and by Robinson (1966) in her discussion of and expansion of Gray's earlier model (Gray, 1960). In Gray's and in Robinson's analyses of the entire reading process, comprehension includes:

1. understanding the literal meaning of a writer;
2. understanding the implied meaning of a writer;
3. assessment of a writer's purpose, frame of reference, assumptions, and generalizations;
4. evaluation by the reader of the writer's ideas;
5. integration of information and ideas of a writer with the reader's information and related experiences.

There is no doubt of the value of broadly based subjective analyses of comprehension as a guide to constructing

measuring instruments and to designing experiments for validating these analyses against reality. Use of the analyses as a guide to constructing learning exercises for the teaching of reading is more questionable though it has been common practice.

SUBJECTIVE ANALYSES BASED ON SPECIFIC STUDIES

The first systematic analysis of comprehension on the basis of experimental data was reported by Thorndike (1917a, 1917b, 1917c). He presented short paragraphs to elementary-school pupils and asked them to write answers to simple questions based on those paragraphs. The pupils were given unlimited time and allowed to refer to the paragraphs as often as they wished while they were composing or writing their responses.

Thorndike found that, even when the pupils understood the meanings of the individual words or phrases in a paragraph, many of them made errors in answering the questions about it. He carefully classified the responses of the children and analyzed the nature of the errors that they made. The resulting data led him to conclude that the pupils were unable to fit together the separate ideas expressed in a paragraph and to give individual words or separate word groups the proper amount of emphasis in relation to one another. For example, the pupils were unable to use connective words or phrases (such as "but" or "on the contrary") to link ideas together in the proper relationships.

It was apparent that certain words or phrases became unjustifiably dominant to some readers. Such an element Thorndike described as "over-potent"; conversely, an element that was unduly weak he described as "under-potent." After rating the underlying importance of knowing the meanings of the words in a paragraph, he wrote:

> The successful response to a question or to a paragraph's meaning implies the restraint of tendencies of many words to be over-potent and the special weighting of other tendencies. This task is quite beyond the power of weak minds and is of the same selective and coordinating nature as the more obvious forms of reasoning in mathematics or science [1917c, p. 114].
>
> Understanding a paragraph is like solving a problem in mathematics. It consists in selecting the right elements of the situation and putting them together in the right relations, and also with the right amount of weight or influence or force for each [1917b, p. 329].

> Understanding a . . . printed paragraph is then a matter of habits, connections, mental bonds, but these have to be selected from so many others, and given weights so delicately, and used together in so elaborate an organization that 'to read' means 'to think' as truly as does 'to evaluate' or 'to invent' or 'to demonstrate' or 'to verify' [1917c, p. 114].

The last quotation formed the kernel of a vast literature on the teaching of reading as a process of thinking. It should be noted, however, that Thorndike fully recognized the place of association or memory for evoking the meanings attached to a particular word or phrase. He also fully recognized the importance of word or phrase recognition as the end product of the process of decoding the written symbols in which words are expressed. His insightful identification of the kinds of mental activities included in the process of comprehension has, over the years, stimulated both subjective and experimental analyses of comprehension that have led to recent multivariate studies in this field.

L. W. Pressey and S. L. Pressey (1921) reported the results of a study in which three reading tests that made use of different types of passages were administered to 112 seventh-grade pupils. Inspection of the intercorrelations of scores on these materials led the authors to conclude that silent-reading performance improved with:

1. freedom from oral reading habits;
2. a large reading vocabulary and an extensive background of information;
3. interest in the material read;
4. good habits of attention and application.

Hilliard (1924) studied the correlations of scores in reading comprehension with six of twelve factors that had been suggested as causes of difficulty in reading. He found that five of these factors were important in comprehension; namely:

1. general intelligence;
2. vocabulary level;
3. organization skill (as measured by the Greene English Organization Test);
4. rate of reading;
5. ability to recall and reproduce (as measured by the Whipple Dutch Homestead Test).

The relationships among several types of scores in comprehension were used by Irion (1925) to show that a given reader was sometimes better in one element of comprehension than in others. For example, he found a product-moment correlation coefficient of .46 between ability to answer factual questions about a passage and ability to get the main point

and to understand the conclusions of a writer. His data showed that knowledge of word meanings played an important part in comprehension.

Gates (1926) studied the roles of visual perception, intelligence, and relevant associative skills in reading, including comprehension as measured by Courtis Silent Reading Test No. 2. He found that some measures of visual perception and mental-age scores on the 1916 Stanford-Binet Intelligence Scale were effective predictors of performance in silent-reading comprehension.

Careful study of the data pertaining to visual perception showed that it is not a unitary concept; individual performance depends on the nature of the material to be perceived. Gates concluded that performance in reading is affected considerably by a reader's ability to perceive word forms (linguistic symbols) and very little by his ability to perceive numerical or geometric symbols. Why this is so and how the perception of linguistic symbols can be improved in the case of children who perform ineffectively in this skill are questions still very much in need of fundamental research.

Gates also found that performance in reading comprehension is rather well predicted by mental-age scores even with perceptual skill held constant. The basic word knowledge and verbal-reasoning skills that largely determine Stanford-Binet mental-age scores have in recent years been subjected to detailed study in experimental studies by Davis (1944, 1968). Gates made practical use of his findings in constructing the Gates Silent Reading Tests, which were first published in 1927 (Gates, 1927).

Carroll (1927) explored in detail children's comprehension of detailed directions and noted that the chief sources of errors made by pupils in this area were in:

1. sentences that involve arithmetic calculations;
2. sentences that contain conditional clauses;
3. sentences that are either highly compact or highly complicated;
4. sentences that contain ideas that are implicit rather than explicit in their expression.

One of the most penetrating and most provocative analyses of comprehension was published by Richards (1929). In Practical Criticism he reported the results of an experiment in which he gave four poems at a time to undergraduates at Cambridge University who were candidates for an honors degree in English literature. He did not provide the authorship of the poems but merely described each set as being "a mixed lot." He asked the students to:

1. read and comment freely on the poems;
2. record the number of "perusals" of each poem required in reading it;
3. hand in written comments one week later.

Over a period of time about 60 percent of the students complied with his request. Clearly a selective factor operated so that we must not regard the comments that Richards received as representative of those he would have received if he had received comments from all of his students. Needless to say, the latter group represented, with respect to facility in comprehending poetry, a highly selected sample of university students in general and a most unusual sample of all English youths at their age levels. Consequently, caution must be exercised in generalizing Richards' conclusions about the elements of comprehension that he identified in analyzing the responses he received. Nevertheless, both his procedures and his conclusions are of intense interest and great value.

Richards found that the errors in comprehension made by his respondents fell into several general categories:

1. failure to discover the plain-sense literal meaning of the content;
2. failure to apprehend the sensory form and flow of words in the metric patterns of poetry;
3. failure to evoke imagery (especially visual imagery) and to recognize and understand the figurative language characteristic of poetry;
4. failure to resist being misled by irrelevant personal memories, experiences, and associations;
5. failure to grasp the writer's meaning because the ideas that are "stock responses" already present in the reader's mind are substituted for or interfere with the writer's ideas or conclusions;
6. failure to respond to poetry without sentimentality; that is, without excessive emotionality;
7. failure to respond appropriately to the emotional content in poetry by suppressing nonintellectual responses;
8. failure to avoid judging impartially the quality of poetry because its writer expresses personal convictions or beliefs that may agree with or differ from those of the reader;
9. failure to avoid judging impartially the quality of poetry because its form or technique differs from the technical presuppositions (or expectations) of the reader;
10. failure to avoid being swayed by expectations about the nature and value of poetry instead of judging the product by its own characteristics.

Richards concludes that there are at least four aspects of meaning that a good reader takes into account:

1. <u>The Sense</u>: what the content actually says;
2. <u>The Feeling</u>: what the writer's emotional feeling is toward what he is writing;
3. <u>The Tone</u>: what the writer's attitude is toward his audience;
4. <u>The Intent</u>: what the writer's purpose is in writing the material.

Although comprehension of poetry emphasizes certain skills on the part of the reader more than does the comprehension of prose, the overlap is very great. Consequently, Richards' comments and conclusions, based on the errors of a highly selected group of readers, are of considerable value in understanding the process of comprehension among a wide range of readers. Inspection of Table 8 shows the influence of Richards' analysis on Davis' outline of skills in reading, first published in 1940 (Davis et al., 1940). Topics IIB1, IIB2, IVA, IVB, IVC, VB, VC, and VD overlap closely with Richards' analysis of comprehension.

Another study of comprehension based on errors by readers was made by Albright (1927). She tabulated and classified 20,003 errors in reading comprehension made by 738 college entrants, basing her work partly on a study by Horning (1927). Miss Albright's classification of student errors in answering questions on what they read follows:

1. Inability to understand the question fully:
   a. Failure to understand the meaning of words used in the question, either words in common use or technical words;
   b. Failure to note the significant or qualifying word, phrase, or clause in the stated question or instruction;
   c. Failure to interpret the question in relation to its context material;
   d. Failure to follow specific directions as stated;
2. Inability to isolate the elements of an involved statement in context:
   a. Inability to isolate the essential idea or element, giving instead general items taken from the sentence, the paragraph, or the question;
   b. Failure to note the potency of restrictive phrases or clauses;
   c. Failure to note or list all of the elements of a thought or statement;
3. Inability to associate the related elements of the context (in cases where the question is relatively easy to comprehend):

a. Failure to make correct associations due to the limit of life experience, either real or vicarious;
b. Failure to make correct associations due to the meagerness of vocabulary, either words in common use or technical words;
c. Failure to make correct associations due to the occurrence of words frequently or emphatically used in other situations;
d. Failure to neglect irrelevant material;
e. Failure to note the tense of a verb, thereby failing to differentiate between present and past;
f. Inability to deduce a specific answer from a general idea or from a series of related ideas;

4. Failure to grasp or retain from given explanations the ideas essential to the understanding of concepts presented later;
5. Failure to see the setting of the context as a whole when specifically questioned as to the text as a unit:
   a. Inability to select the title of a paragraph;
   b. Failure to judge correctly materials preceding and following a paragraph;
6. Irrelevant answers--careless, irrational or impossible answers, possibly due to peculiar individual experiences.

Albright's list is detailed and specific but most of the points may be fitted into broad groups of skills like

1. Knowledge of word meanings;
2. Ability to grasp detailed facts;
3. Ability to weave ideas together and make deductions;
4. Ability to follow the syntactical structure of a passage;
5. Ability to consider a passage objectively without being overwhelmed by personal experiences and feelings.

MULTIPLE-REGRESSION STUDIES

Holmes Original Substrata-Factor Study

Beginning in the 1920's a large number of experiments were conducted that related many skills to a variety of measures of reading ability. For example, studies by Pressey and Pressey (1921) and by Gates (1926) made use of correlational techniques for this purpose. However, the first large-scale study designed to estimate the independent portions of the variance of comprehension scores accounted for by a number of variables chosen because of their reported relationship

to the reading process was made by Holmes (1948, 1954), who stated (Holmes, 1954):

> While the amount of research on reading disabilities is voluminous, no investigator, to the writer's knowledge, has tried to discover in a constellation the organization of the sub-strata factors which underlie speed and power of reading within a single sample at the college level. This is the task of the present study [p. 17].

Holmes defined two aspects of reading to serve as criteria in his study. The first was "power of reading," by which he meant the ability to comprehend and apply rather difficult textbook material in generous time limits. This variable has commonly been called "level of comprehension." The second was "speed of reading," by which Holmes meant the rate of comprehension of relatively easy material. It should be noted that he did <u>not</u> mean number of words read per minute (with or without separate checks on comprehension). Therefore, in this paper Holmes's second criterion variable will be referred to as "speed of comprehension."

It may be argued that when scores in "level of comprehension" and "speed of comprehension" are to be compared or are to be used as criteria to be predicted by the same set of independent variables it would be desirable to measure both "level of comprehension" and "speed of comprehension" in reading materials of the same kind and difficulty. The fact that Holmes accepted the prevailing view in 1948 and measured level of comprehension in the reading of difficult material and speed of comprehension in the reading of easy material constituted a minor fault in the design of his study.

Measurement of the criterion variable of level of comprehension was accomplished by summing equivalent C-scores on five subtests of the Diagnostic Examination of Silent Reading Abilities, Part III, Senior Division, Form M (Dvorak & Van Wagenen, 1939). In the present writer's judgment, the quality of items in this examination leaves much to be desired and the passages do not have the variety and sparkle that one would like to see in material to be used as a basis for comprehension items. The validity of the scores as measures of level of comprehension is probably adequate for practical school purposes but possibly not for research purposes.

The criterion variable of speed of comprehension was measured by the average of standard measures on the Minnesota Speed of Reading Test for College Students (Eurich, 1936) and the Diagnostic Examination of Silent Reading Abilities, Rate of Comprehension Test, Part I, Senior Division, Form M (Dvorak & Van Wagenen, 1939). Both of these tests measure the ability of the examinee to detect an absurd word inserted near the

end of a rather short paragraph of easy material. This ability is not ordinarily called into play in natural reading situations and leads test-wise examinees to alter their normal reading habits to an unacceptable degree. Consequently, the validity of the criterion measure of speed of comprehension appears questionable. This is particularly regrettable because more valid measures of speed of comprehension were available in convenient published form throughout the 1940's.

The independent variables were 37 measures of functions that had been suggested as of importance in determining reading ability. Of these, 20 were selected on the grounds that their correlations with the two criterion variables "gave preliminary promise of making an independent contribution which would help account for individual differences in speed of reading [Holmes, 1948, p. 65] and in power of reading ability [Holmes, 1948, p. 68]." Of those omitted, 14 were personality variables, one was rate of reading with the eye-movement camera, and two were cognitive variables: Interpretation of Data and College Grade-Point Average. The level-of-comprehension criterion variable was used as an independent variable in predicting the speed-of-comprehension criterion variable, and vice versa.

The Wherry-Doolittle test-selection method (Wherry, 1946) was then employed to obtain the partial regression coefficients for the four variables that contribute most to predicting scores in level of comprehension and in speed of comprehension. Unfortunately, the partial regression coefficients for all 21 variables were not obtained.

Table 1 shows the partial regression coefficients expressed in standard-measure form together with the percentages of the variance of the criterion variable that is overlapped by each independent variable. Caution must be exercised in the interpretation of these data because with only 126 examinees in the sample, the beta weights are subject to considerable fluctuation. Broadly speaking, the data suggest that accuracy and speed of word perception and level of vocabulary may constitute the major determinants of the speed-of-comprehension criterion score. A specific element, either psychological or physiological, that affects the span of recognition in reading is also operative.

The level-of-comprehension criterion scores seem to be associated with level of vocabulary, general reasoning facility, and verbal relationships. A specific element related to eye movements during reading is also present. The negative sign of the beta weight for number of fixations per 100 words reflects the fact that high standard measures on this variable represented poor reading habits, as indicated by a large number of regressions per 100 words of running text. Apparently, 7-8 percent of the criterion variance is associated with this

TABLE 1

FOUR VARIABLES FOUND BY HOLMES[a] TO BE THE BEST PREDICTORS OF SPEED OF COMPREHENSION AND OF LEVEL OF COMPREHENSION (N = 126)

Variable	Beta weight	Uncorrected percent of criterion variance
Speed of Comprehension		
9. Word Discrimination	.396	27.56
11. Word Sense	.344	23.19
23. Span of Recognition	.143	5.59
22. Power of Reading	.017	.01
Level of Comprehension		
3. Vocabulary in Context	.507	39.24
1. Otis Quick-Scoring IQ	.382	26.89
2. Perception of Verbal Relations	.127	7.62
20. Number of Fixations per 100 Words	-.140	3.98

[a]Holmes (1948, pp. 68-70).

variable; as number of regressions per 100 words drops, level of comprehension tends to be better to the degree represented by a zero-order correlation coefficient of .104 (Holmes, 1954, p. 67).

By and large, the regression analysis does not seem to have been of great value in suggesting skills that are critical to speed of comprehension or level of comprehension. The results indicate that efforts to improve a pupil's word perception, level of vocabulary, and facility in verbal reasoning might be helpful in reading instruction. Since eye-movement habits have been found to be a result of and not a cause of difficulty in comprehension, it is doubtful that training in this area is of much value.

For reasons that will be considered later, the secondary or tertiary regression analyses used in substrata factor analysis, while legitimate in themselves, must not be used to draw firm conclusions about the nature of the parts of the variances of the variables shown important in the primary analysis.

Singer's Study in Grades 3-6

The second large-scale regression analysis of reading comprehension was made by Singer (1965). The plan of the study was similar to that of Holmes's (1948) study, but the variables were somewhat different and were administered to 927 pupils in grades 3-6 in Alvord, California. The samples were judged to be reasonably representative of the American populations of pupils at these grade levels.

Two criterion variables and 26 independent variables were used in the study. A subsample of 50 pupils per grade (25 boys and 25 girls) drawn randomly from the groups of boys and of girls in the sample was used to obtain reliability coefficients for each of the 28 variables. Because the subsample included pupils at four grade levels, these coefficients cannot be meaningfully compared with the single-grade reliability coefficients properly reported for these and other tests in test manuals. If they had been based on the 927 pupils in the sample, they could have been used to estimate the true intercorrelations of the 28 variables since the intercorrelation matrix used in Singer's multiple-regression analysis was also based on scores from pupils in grades 3 through 6. As would be expected, the mean scores on the 28 variables increased markedly from grade 3 through grade 6, though not by equal proportions of their raw scores; hence, both their intercorrelations and reliability coefficients are markedly and differentially inflated over the values that they would take within any one grade. Since no evidence is offered to indicate that growth in the 28 variables, as shown by increases in mean raw scores from grade 3 to grade 6, is proportional to growth expressed in a common interval scale (like Flanagan's Cooperative Scaled Scores or Gardner's K Scores), we may assume that the matrix of intercorrelations used by Singer to obtain partial regression coefficients is distorted to an unknown extent. Consequently, interpretations of the findings must be made with caution.

After discussing the contributions of specific tests to the variance of the criterion scores, the Speed-of-Reading scores from the Gates Reading Survey (Gates, 1953, 1958), Singer concludes that the skills found to "account for" independent parts of the variance of the criterion scores shift from a predominance of visual-perception abilities (such as speed and accuracy of word perception) at the third-grade level to a more equal balance of visual-perception abilities and knowledge of word meanings at the sixth-grade level. He also concludes that systematic exercises to increase vocabulary level and to sharpen accuracy of word perception should be stressed in the teaching of reading in grades 3-6. The fact that the study yields results that coincide with practices in the teaching of reading that have been widespread over many years allows greater confidence to be placed in

the findings than would otherwise be possible. Presumably, the next steps would be (a) to determine experimentally the types of learning exercises that are most efficient for increasing vocabulary level and accuracy of word perception; and (b) to conduct controlled experiments to determine the effect on pupils' reading of using such exercises systematically.

It must be kept in mind that the function actually measured by the Speed-of-Reading section of the Gates Reading Survey is speed of comprehension of materials much easier than middle-grade pupils are ordinarily asked to read in school. This fact may partly explain why word knowledge and speed and accuracy of word perception constitute the only variables that are found to be of great importance in this study. Part of the explanation may lie in the fact that more specific skills in comprehension were not the primary functions measured by any of the independent variables.

Holmes-Singer Study in Grades 9-12

The third large-scale multiple-regression study of comprehension in reading was reported by Holmes and Singer (1966). They drew a sample of 428 pupils who were attending the University of California Demonstration Summer School of 1953. Of these, 28 were in grade 8, 2 were in college, and 6 were over 21 years of age. This group of 28 pupils was eliminated; the 400 remaining were all in grades 9-12 and not over 21 years of age. Regression studies were then conducted on the basis of all 400 pupils and, separately, on the basis of boys (N = 211); girls (N = 189); the 108 pupils who had the highest scores on a highly speeded recognition-vocabulary test; the 108 pupils who had the lowest scores on this test; the 108 pupils who had the highest scores on the speed-of-comprehension criterion measure; and the 108 pupils who had the lowest scores on this measure.

The extent to which intercorrelation matrixes based on the entire sample of 400 pupils and on the designated subsamples may be regarded as representative of matrixes that would be obtained if the entire American population of pupils enrolled in grades 9-12 were given the same tests is unclear. However, the fact that the scores of pupils covering so wide a grade and age range were included in the computation of the intercorrelation matrix makes results of the study somewhat inapplicable to pupils in any one of the grades. It seems likely that the formation of subsamples according to score on a highly speeded vocabulary test or on the speed-of-comprehension criterion measure would tend to result in categorizations that would place pupils in grades 9-10 in the "low-scoring" subsamples and pupils in grades 11-12 in the "high-scoring" subsamples.

Two basic criterion variables were used in these studies: first, power of reading; and, second, speed of reading. As a criterion measure of power of reading, use was made of the Dvorak-Van Wagenen Diagnostic Examination of Silent Reading Abilities, Junior Division: Part III, Form M (1939). It must be noted, therefore, that the variables found by multiple-regression analysis account for the variance of scores derived from this test--not of untimed depth of comprehension in reading, unless the test can reasonably be regarded as an adequate measure of that variable. Let us, therefore, consider the adequacy of this test for the purpose. First, it was intended for use in grades 7-9, yet it was used by Holmes and Singer for testing pupils in grades 9-12. Second, the quality of its items leaves a good deal to be desired. A sample paragraph and items follow:

> It was Perez, a friar, on whom Columbus called with his little son Diego, and explained his need for men and ships to prove the world is round. The friar interested his friend, Queen Isabella of Spain, in the plans of Columbus. But when the three ships that carried Columbus to America sailed from Spain, Diego was left to stay at the palace of the Queen until his father should come back.
>
> A. The paragraph is mainly about
> 1 Perez, the friar
> 2 Queen Isabella
> 3 the ships in which Columbus sailed
> 4 the voyage of Columbus
> 5 the palace of the Queen
>
> B. Perez had been a friend of
> 1 Columbus
> 2 Diego
> 3 Queen Isabella
> 4 Diego's father
> 5 the father of Columbus
>
> C. Diego was left at home because he was
> 1 a friar
> 2 too young
> 3 not interested
> 4 afraid to go
> 5 didn't know his father was going
>
> D. When Diego was left at the palace, he was
> 1 happy
> 2 glad
> 3 relieved
> 4 joyous
> 5 unhappy

Since the passage lacks unity, an item like A should probably not be written to test comprehension of it because no truly adequate keyed response can be provided. Clearly, choice 4 is keyed, but this is evident only because the other choices are less adequate than choice 4, not because choice 4

truly tells what the paragraph is mainly about. In item B, choices 1 and 4 mean the same thing, so neither of them can be keyed if the item is to have only one answer. Since either of them alone might reasonably be defended, the stem should perhaps read: "The passage states that Perez was a friend of." In item C, choice 5 does not fit the stem grammatically so it is unlikely to be popular. It is unusual to find this type of error in a published test. There is nothing in the passage, explicit or implicit, to make any choice in item D unequivocally correct. But since choices 1, 2, and 4 have almost the same meaning in this context, none of them can be keyed if the item is to have only one answer. Therefore, the reader knows that he should probably mark either choice 3 or 5. Since a "little son" usually wants to be with his father, choice 5 is the most plausible keyed response. But this inference is based on observations of children's behavior wholly apart from the passage. A more defensible form of the item might have used the stem, "When Diego was left at the palace, it is most likely that he felt" and "disappointed" as the keyed choice 5.

The independent variable representing speed of reading in the regression analysis was the Van Wagenen Diagnostic Examination of Silent Reading Abilities, Part I, Form B. Scores on this test show the speed with which examinees can understand short paragraphs well enough to recognize what word toward the end of each paragraph is absurd in its context. As mentioned previously, this skill is scarcely ever required in real-life reading or studying.

In summary, the dependent variables used by Singer and Holmes (1966) for measuring both speed of comprehension in reading and level of comprehension in reading were of doubtful validity for their intended purpose; it seems fair to say that better measures were readily available.

Examination of the independent variables leads one to doubt the content validity of some of them for measuring what their titles imply. For example, Test 8 is labeled Vocabulary in Context, yet the sample item reads:

He felt very <u>sad</u>.
1 timid
2 happy
3 weary
4 sorrowful
5 hungry

The context provided for the word "sad" is entirely superfluous; the item can be answered with complete confidence by an examinee who knows that "sad" means "sorrowful." So this item measures knowledge of the meanings of words presented in isolation, as do the sample items for Tests 1 and 9 (although

these tests are labeled Visual Verbal Meaning Test and Vocabulary in Isolation Test, respectively). It is likely that observed differences in their intercorrelations result from the fact that Test 1 was highly speeded (4 minutes allowed for 50 four-choice items) while Tests 8 and 9 were unspeeded. The relatively large contribution of Test 1 to the variance of the speed-of-reading dependent variable and the relatively large contributions of Tests 8 and 9 to the variance of the power-of-comprehension dependent variable are probably attributable to this fact. In other words, since all of the tests measure principally memory for word meanings, differences in their correlations with each other and with the dependent variables are probably produced by differences in "speed of mental operation" in responding to verbal assocations. Holmes and Singer do not seem tc have taken this consideration into account in the interpretation of their findings.

Data provided by Holmes and Singer (1966, p. 42) show that the zero-order correlation coefficient between the speed-of-reading and power-of-reading criterion scores was .594 in the sample of 400 high-school pupils tested. This relationship is somewhat lower than that commonly found among secondary-school pupils for the correlation between independent tests of speed of comprehension and level of comprehension when the same types of comprehension skills are measured by both tests and only the factor of speededness is varied. Thus, both statistical data and subjective judgment of the skills measured by the dependent variables used by Holmes and Singer for their regression analyses lead to the conclusion that differences in the substrata factors found at Level I in the two analyses result from differences in the abilities measured by the criterion variables as well as from differences in the abilities brought into play by secondary-school pupils for two purposes in reading--comprehending as fast as possible and comprehending as deeply as possible without regard to the time required. It might have been interesting to have removed the power-of-reading variance from the speed-of-reading criterion variance by part correlation. The independent variables would not have been altered and the regression analysis would then have shown the contribution made by each of the independent variables to the part of speed-of-comprehension variance that is independent of power-of-comprehension.

The results of the Level-I regression analyses done by Holmes and Singer (1966) are extensive and can only be summarized briefly here. The variance of speed of comprehension in their entire sample of 400 cases probably has fairly large components that might be termed:

1. Knowledge of word meanings,
2. Visual memory of word forms (spelling),
3. Reasoning facility,

4. General information (partial variance of the Auding test),
5. Interest in literary rather than computational activities.

The variance of level of comprehension in reading probably has fairly large components that might be termed:

1. Knowledge of word meanings,
2. Reasoning facility,
3. General information (partial variance of the Auding test),
4. Interest in literary rather than mechanical activities.

This interpretation of the Level-I data differs from that given by Holmes and Singer (1966, pp. 62-78), whose interpretation seems to be based on the impression that each of their independent variables is made up of homogeneous variance measuring the function named in its title.

In comparing the "substrata factors" used by boys with those used by girls in speed of comprehension, Holmes and Singer correctly point out that the largest difference lies in the fact that the spelling test accounts for 8.5 percent of the variance among boys and that the homonymic-meaning test accounts for 14.6 percent of the variance among girls. It is possible that both of these tests measure visual memory for word forms and that only chance determines (in the small samples they used) which test happens to have the larger partial regression coefficient for predicting the criterion measure of speed of comprehension. Comparison of the "substrata factors" used by boys with those used by girls in level of comprehension shows few differences. If Auding-test variance that is not partialed out by word knowledge and reasoning ability is specific general-information variance, the fact that the Range of Information test shows a larger beta weight among boys than among girls may reflect only sex differences with respect to items on that test.

Comparisons of the "substrata factors" used by the 108 pupils who scored highest on a speeded vocabulary test with those used by the 108 pupils who scored lowest on this test show that, with respect to the speed-of-comprehension criterion, the speeded variable used to form the two groups "accounts for" more of the criterion-score variance in the "high" group than in the "low" group. In the latter, less speeded vocabulary tests account for the largest parts of the criterion-score variance. With respect to the level-of-comprehension criterion, there is very little difference in the "substrata factors" that appear to be important in the high-vocabulary-level and low-vocabulary-level pupils.

Comparisons of the "substrata factors" used by the 108 pupils who scored highest on the level-of-comprehension criterion variable and by the 108 pupils who scored lowest on this variable shows that reasoning facility and general information appear to account for a larger proportion of the criterion-score variance in the "high" group than in the "low" group. Given the very small numbers of degrees of freedom (108 - 55 = 53) available for obtaining beta weights for the intra-group comparisons, great caution must be exercised in the interpretation of the data. Only the grossest differences in the Level-I results should be considered. The writer hesitates to venture interpretation of even these data.

Comments on Substrata-Factor Techniques

A multiple-regression analysis provides an estimate for each independent variable (in the set of variables used in a given sample) of the extent to which variations in scores on the dependent variable are uniquely associated with variations in scores on that particular variable. To expand this statement, if every item in a test measured exactly the same skill, all variations in scores from person to person on that test would be attributable to differences in the examinees' levels of performance in that skill. The variance of such scores would be homogeneous and the test would be described as "univocal." However, tests can rarely be so described; each test usually measures several discrete skills. Sometimes, items that actually measure one skill apiece, but not the same skill, are incorporated in a single test so that scores on the test generate variance that is attributable to several different skills. More often, each separate item in a test measures a composite of several skills so that the test variance is inevitably attributable to several different skills. Variance of this kind is described as heterogeneous. Multiple-regression analysis yields an estimate of the proportion of the variance of the dependent variable that covaries with each uncorrelated segment of the variance measured by all of the independent variables. Some of these uncorrelated segments are positively related and some are negatively related to scores on the dependent variable. For our purposes in understanding the nature of first-level substrata factors, the important point is that a positive beta weight attached to one of the tests used as an independent variable means that some element of this test's variance, which is independent of other sources of variance used in the regression equation for predicting criterion scores, covaries directly with the variance of the dependent variable. Conversely, a negative beta weight attached to one of the tests in the set of independent variables means that some element of this test's variance covaries inversely with the variance of the dependent variable. However, it must be noted that the test's variance as a whole may covary either positively or negatively with the variance of

the dependent variable. That is, predictor-test scores that have a negative beta weight in a multiple-regression equation for predicting criterion-test scores may correlate either negatively or positively with those same criterion-test scores.

Consequently, in the interpretation of substrata factors at Level I, it is important to recognize that the independent contributions to criterion-score variance identified mathematically by the multiple-regression procedure cannot usually be properly identified simply by assigning to them the names of the predictor tests involved. Each packet of predictor-score variance that "accounts for" a separate portion of criterion variance usually represents only one element of the total variance of the predictor test with which it is identified by a beta weight. And the relative magnitude of this beta weight reflects the presence of that element in <u>other</u> predictor tests. To make inferences about the psychological nature of the elements in the predictor tests that add significant contributions to the predicted variance of the criterion variable is a complex and delicate process that requires intimate knowledge of the skills involved in each predictor variable and insightful understanding of what is yielded by multiple-regression analyses. Interpretation of the results of factor analyses and component analyses is equally complicated and difficult.

Though the identification of substrata factors obtained by Holmes in a Level-I analysis is not easy, the process makes use of legitimate data. When any one of the independent variables found in the Level-I analysis to include elements that make significant contributions to the criterion-score variance is used as a criterion for a Level-II regression analysis, the data obtained are again legitimate and subject to the usual kinds of interpretations that may properly be made. However, these data cannot properly be used to estimate the contributions to the Level-I criterion-score variance made by Level-II predictor tests. That has already been accomplished in the Level-I analysis since the Level-II predictor tests were included in that analysis. Neither can we properly use the data from the Level-II analysis to identify the operational or psychological nature of the elements in the Level-I predictor tests that contributed significantly to the original criterion variance in the Level-I analysis. For example, in the study by Holmes and Singer (1966), it is possible (even likely) that memory of word meanings is the principal element in Test 1 that predicts the variance of the speed-of-comprehension criterion scores in the Level-I analysis. It is likely that the beta weights attached to some of the Level-II independent variables for predicting scores in Test 1 reflect the presence of elements in Test 1 that do <u>not</u> predict the variance of the speed-of-reading criterion scores in the Level-I analysis. In any event, the procedures used by Holmes and Singer (1966) leave this matter undetermined.

Consequently, it is inappropriate to estimate the proportion of the variance of an original Level-I criterion variable that overlaps the variance of a particular Level-II predictor simply by multiplying the proportion of the original criterion variance that overlaps a given Level-I predictor variable by the proportion of the latter that overlaps the variance of the particular Level-II predictor variable. Unless the variance of the given Level-I predictor variable were homogeneous (which is unlikely), this procedure could yield the desired result only if the criterion variable for the Level-II analysis consisted of scores in that part of the variance of the given Level-I predictor variable that was obtained in the Level-I analysis for predicting scores in the original criterion variable.

Needless to say, if it is unlikely that Level-II substrata analyses can yield meaningful data regarding the original criterion variable of the Level-I analysis, it is virtually impossible for additional analyses (at Level III, et seq.) to do so. Broadly speaking, the statistical technique for substrata analysis suggested by Holmes (1948, 1954) does not permit the type of identification of substrata factors that he envisaged. This conclusion does not mean that multiple-regression procedures cannot yield data that are helpful in identifying sources of unique variance in a set of independent variables that covary significantly (at some preselected level of probability) with scores that constitute a valid measure of comprehension in reading specified types of material. To obtain such data, the desired predictor and criterion variables should be administered to a very large sample of examinees representative of the desired population. The sample should be randomly separated into two halves. Beta weights based on each half of the sample should be used with the intercorrelations of the variables in the other half of the sample. This makes available two cross-validated estimates of the proportion of the variance of the criterion variable that overlaps the variance of each predictor variable that covaries with the criterion variance. From these data, perceptive inferences about the psychological identity of the variables may be made. We must conclude, however, that the interpretations made by Holmes of data obtained in his substrata investigations of the nature of the reading process are not statistically sound and may lead to misleading conclusions.

For additional comments on methodological aspects of Holmes's substrata-factor studies, interested readers are referred to papers by Carroll (1968), Plessas (1964), Raygor (1966), Spache (1964), Sparks and Mitzel (1966), and Wark (1966). Singer (1969) replied at some length to Carroll's critique, which was the longest, the most penetrating, and (in the present writer's judgment) the most trenchant of the comments on the substrata-factor techniques.

Uniqueness Study by Davis

Use of multiple-regression techniques to estimate the unique nonchance variance in each of eight fundamental skills of comprehension in reading among mature readers was reported by Davis (1967, 1968). This technique has considerable merit in studying the nature of comprehension in reading because, in a properly designed experiment, it makes possible estimation of the proportion of the variance of each separate skill in a set of skills that is unique nonchance variance. These results are important in research in reading comprehension because they permit identification of the skills in comprehension that are sufficiently different from others to make separate teaching of them and providing practice in them of particular importance since they may not be learned in the course of practicing other skills. Needless to say, profitable application of uniqueness analysis to the process of comprehension in reading requires that the set of skills actually used in the analysis include all of the important skills, that these be measured separately, and that the measuring instruments employed yield scores that are valid measures of the skills that they represent.

It has long been recognized that an estimate of the unique variance of a test in any given set of tests can be obtained by subtracting an estimate of its communality with other tests in the set from an estimate of its reliability coefficient in the same sample used to estimate the communality. As mentioned elsewhere in this paper, Harris (1948) employed this procedure to estimate the unique nonchance variance of several reading tests. He found none in any of the tests that he used.

Flanagan (1959) avoided the iterative process of making a good estimate of communality by using the variance of standard measures in each test in a set that can be predicted from the best-weighted combination of standard measures in all of the other tests in the set as the estimate of the communality of each test in that set. He used parallel-forms reliability coefficients and estimates of the predictable variance of each test to determine the unique nonchance variance of each test.

Shaycoft (1964) pointed out that bias in the estimate of the squared multiple correlation coefficient can best be removed by cross validation. This can be accomplished by using the beta weights based on one-half of the available cases with the test-criterion coefficients based on the other half of the available cases, and vice versa; or it can be accomplished by preparing parallel forms of the tests, administering them to the same sample, and using the beta weights from the administration of one form of the tests with the test-criterion coefficients from the administration of the

other form of the tests, and vice versa. It should be noted that experimental cross validation yields an unbiased estimate of the squared multiple correlation coefficient whereas Wherry's estimation procedure (Wherry, 1931) is known to be slightly biased.

In addition to cross-validating estimates of unique variance, Davis (1960) also corrected these estimates for attenuation by using the reliability coefficients for each variable and each cross-validated composite score in turn. His procedure, therefore, was similar to one using an equation presented by Horst (1966, equation 20.5.25, p. 333) for estimating specificity. Consequently, Davis' study provides cross-validated estimates of the proportion of the nonchance variance of each variable that is unique to that variable in the set of eight employed.

The selection of skills considered most important in comprehension among mature readers was based on Davis' previous work on the fundamental factors of comprehension in reading (Davis, 1941, 1944). The original test of nine skills was reduced to eight by combining skill 4 (ability to select the main thought of a passage) with skill 6 (ability to answer questions that are answered directly in the passage but not in the words in which the question is asked). This combination is listed as number 3 of the eight skills used in Davis' uniqueness analysis and listed in Table 2. It will be noted in Table 3 that the variance of component IX is very small and is probably made up of variance highly specific to skill 4 in that table.

TABLE 2

EIGHT SKILLS OF COMPREHENSION IN READING AMONG MATURE READERS USED BY DAVIS IN HIS UNIQUENESS ANALYSIS

Skill number: Uniqueness analysis (1967)	Skill number: Component analysis (1941)	Skill
1	1	Recalling word meanings
2	5	Finding answers to questions answered explicitly or merely in paraphrase in the content
3	4,6	Weaving together ideas in the content
4	7	Drawing inferences from the content
5	9	Recognizing a writer's purpose, attitude, tone, and mood
6	2	Drawing inferences about the meaning of a word from context
7	8	Identifying a writer's technique
8	3	Following the structure of a passage

TABLE 3

PERCENT OF NONCHANCE VARIANCE OF EACH OF EIGHT SKILLS THAT IS UNIQUE IN THE SET OF SKILLS USED[a]
(N = 988)

Skill	Cross validation by: Items and day	Cross validation by: Items only
1. Recalling word meanings	35	29
2. Finding answers to questions answered explicitly or merely in paraphrase in the content	-1	8
3. Weaving together ideas in the content	13	7
4. Drawing inferences from the content	5	5
5. Recognizing a writer's purpose, attitude, tone, and mood	23	18
6. Drawing inferences about the meaning of a word from context	14	8
7. Identifying a writer's technique	8	3
8. Following the structure of a passage	15	12

[a]Davis (1968, p. 541). The negative entry in the table is probably a chance deviation from a zero or slightly positive value.

To measure each of the eight skills, 40 items were used. These were tried out in two parallel forms, A and B, administered without time limit to juniors and seniors in academic high schools. Biserial correlation coefficients were then computed between total scores on each one of the eight groups of items in Form A and item scores on each of the 160 items in Form B. Conversely, biserial correlation coefficients were computed between total scores on each one of the eight groups of items in Form B and item scores on each of the 160 items in Form A. By this means, inflation in total score-item score coefficients (caused by inclusion of an item in the total score with which its scores are correlated) was avoided and the raw biserial coefficients were directly comparable. The 24 items measuring each of the eight skills that they were intended to measure better than they measured other skills were then selected. Each group of 24 items was next split into two groups of 12; eight groups of 12 items each were assembled to provide two parallel forms (C and D) of 96 items each. Both of Forms C and D were administered without time limit to nearly 1,000 juniors and seniors in academic high schools. There was no overlap of examinees in the groups that took Forms A and B and the groups that took Forms C and D.

Many matrixes and submatrixes of items could have been formed for analysis. Davis used 14 of them to obtain 224 estimates of the proportion of the nonchance variance of each skill variable that is unique to it in the set of eight. These are summarized in Table 3 by skill in terms of the cross-validation procedures used to obtain them.

Skill 1 shows the largest percentage of unique variance. About 32 percent of the nonchance variance of recognition-vocabulary items does not overlap the nonchance variance of any other of the eight skills. Presumably, this means that specific knowledge of the 24 words chosen for testing constitutes a large part of the variance of these tests. It seems reasonable to believe that longer lists of words of more general utility would probably show smaller percentages of unique nonchance variance. In this case, a conscious effort was made to avoid words with obvious roots that would permit inferring the meaning of the word from its constituent parts. Effort was also expended to minimize the likelihood that the correct response to an item could be identified by comparing distracters. The results suggest that specific memory may well have played a larger role in determining scores on skill 1, as measured in this study, than is commonly the case.

Skill 5 (drawing inferences from the content) showed the second largest percentage of unique nonchance variance. About 20 percent of the variance of the test items used to measure this skill are unique in this set. Probably most of the nonchance variance of skill 2 (drawing inferences about the meaning of a word from context) overlaps with the variance of skills 4 and 5. Skill 2 seems to have very little unique nonchance variance. Three other skills that show appreciable percentages of unique variance are skills 3, 6, and 8.

It is interesting to compare these findings with those of Davis' earlier component analysis (Davis, 1941, 1944). In the latter, two major components of comprehension in reading among mature readers were found: Knowledge of word meanings and Reasoning in reading. It is obvious that the two skills found in the uniqueness analysis to have the largest percentages of unique nonchance variance represent the same fundamental skills.

From the data it is clear that comprehension in reading among mature readers is not a unitary mental skill. It is, apparently, a composite of at least five or six underlying mental skills. Whether there is a hierarchy of these skills by which one or more must be available to the reader before he can call on others is not shown by our data. Chapman is now engaged in a study at the University of Chicago that may provide information about this point (Chapman, 1969). A discussion of her formulation of three models of comprehension in reading is presented in a later section of this paper. The

problem of hierarchies of skills in listening comprehension and in reading comprehension has also been considered by Hackett (1968).

FACTOR-ANALYSIS STUDIES

Use of Factor Analysis

By the middle 1930's, many research workers in reading recognized the possibility of determining by principal-component analysis or by factor analysis whether the long list of operational skills that had been suggested as elements of the mental process called "comprehension in reading" could be reduced in number by eliminating redundancies. Essentially, principal-component analysis yields a set of derived variables, the variance of each of which is made up of a portion of the variance of each original variable that measures the same function. Thus, the variance of each component is "homogeneous" in the sense that the variance attributable to each of the original variables that make up a component overlaps to the same extent with the variance of any external criterion with which it may be correlated.

Since the techniques used in obtaining the derived variables can make them uncorrelated with one another and account, successively, for as much as possible of the total variance of a set of original variables, great economy in thinking about each component may be attained. In one sense, the components may be regarded as more fundamental than the original variables. The principal components of a set of skills measuring operationally different aspects of comprehension in reading, for example, may reasonably be considered to represent fundamental uncorrelated mental elements of comprehension. Their adequacy, however, depends on (a) the extent to which the original set of variables measures all of the mental elements involved in comprehension and on (b) the reliability of the original variables.

The first consideration is dependent on the insight and care with which the original variables were conceived and constructed and on the inclusion of all of the nonchance variance of these variables in the analysis. It is well known that the variance of any variable may include common variance (that is, variance that is identical with part or all of the variance of two or more variables in the set to be analyzed), unique variance (that is, nonchance variance that is not present in the variance of any other variable in the set), and error variance (that is, variance attributable to chance elements and to irrelevant nonchance elements). In constructing tests to measure what appear to be operationally different skills in reading, great care must be taken to have each test measure all of the elements that make it different from other

skills as well as those elements that make it like other skills. In short, each test should be a truly valid measure of the skill it is intended to measure or come as close to that goal as insight, ingenuity, effort, and time will permit.

With scores on insightful and conscientiously constructed variables available, the research worker must include both their common and their nonchance unique variance in component analysis. If he analyzes only the common variance of his original variables, the components he obtains cannot represent the presence of the nonchance elements that are unique to each test in the set he used. Thus, in practice, the distinctive elements of each operational skill in reading, which represent the elements that are usually the most difficult and the most time consuming to incorporate in test items, are thrown away if the principal-components method is used to analyze only the common variance of a set of variables. This point must be kept in mind when factor studies of comprehension in reading are reported in the literature. Despite the fact that Davis has pointed this out (1941, 1944, 1946), a survey of the literature in reading comprehension shows that the issue is misunderstood. Davis (1941) applied the principal-components method to the total variance of a set of nine tests, which he had constructed in 1939. Thurstone (1946) reanalyzed the data and obtained results different from Davis' largely because his analysis did not include the nonchance unique variance of the tests; thus, while his results were mathematically correct for the common-factor variance he analyzed, they were not helpful in identifying fundamental elements of comprehension in reading. On the other hand, Davis' analysis (by a method chosen for use because of its appropriateness for the purpose of his study) indicated that six uncorrelated components of comprehension were present in the tests he used that yield scores with reliability coefficients significantly greater than zero at the .08 level (1944, p. 194). It would be methodologically unsound to ignore the existence and interpretation of such components.

This brings up another point with respect to the interpretation of factor studies that requires comment. The variance of any one component is dependent partly on the number of variables that contribute to its variance and largely on the proportion of each variable's variance that is contributed to the component. If the variances of several of the original variables overlap greatly (as would be the case, for example, if several different types of vocabulary tests were included with tests of other more nearly uncorrelated reading skills in a set in which all variables were expressed as standard measures), a component representing these overlapping variables is likely to appear and to have a variance that is large compared with the variances of other components. The comparative sizes of the component variances indicate the extent to which each uncorrelated component accounts for the

variance of all of the original variables that were analyzed. But their comparative sizes do not necessarily indicate the relative importance of each component in the trait of which all of the tests in the set are a part. The importance of a component, in this sense, could be ascertained from its comparative size only if the analysis were performed on a matrix of variances and covariances of variables properly constructed and weighted to form a satisfactory quantitative representation of the trait being studied. This matter has been discussed by Kelley (1935) and Davis (1947, pp. 158-160).

Among the unrotated components yielded by an analysis of the total variance of a set of variables, psychological interpretation should be carried out only for those that yield scores having reliability coefficients significantly greater than zero at some preselected level. If this rule is not followed, a good deal of effort may be expended in trying to interpret or to make use of derived variables that capitalize on chance and that might not reappear if the original variables were administered to another sample drawn at random from the universe of which the original sample was representative. Likewise, it seems essential to include in analytic rotation procedures all of the unrotated components that yield scores having reliability coefficients significantly different from zero at a fairly stringent preselected level (Davis, 1946, pp. 250-251; Levine & Hunter, 1971). If this is not done, a great deal of significant information may be lost.

With these general considerations pertaining to the use of component or factor analysis in mind, let us consider some well-known research studies on comprehension in reading that make use of what is widely called factor analysis.

Factor-Analysis Studies in Reading

One of the first studies in this category was that reported by Feder (1938), which was based on data obtained by Adler (1936) in an unpublished master's thesis. Feder tested 99 college sophomores enrolled in elementary psychology at the University of Iowa with six measures. Two of these measured ability to answer factual questions; two of them measured ability to make inferences from the material read; one measured appreciation of the material read; and one measured speed of comprehension of easy material. The six scores obtained for each examinee were experimentally independent but the items in tests 4 and 5 were based on the same 15-paragraph passage. No reliability coefficients for the six variables were obtained. The intercorrelation matrix is shown in Table 4. The common variance of the variables was factor analyzed by the centroid method and the resulting factors were rotated to an orthogonal simple structure.

TABLE 4

INTERCORRELATIONS OF READING TESTS
Reported by Feder[a]

	Variable 1	2	3	4	5	6
1	-	.30	.24	.44	.25	.27
2	.30	-	.29	.36	.21	.22
3	.24	.29	-	.48	.45	.32
4	.44	.36	.48	-	.41	.25
5	.25	.21	.45	.41	-	.10
6	.27	.22	.32	.25	.10	-

1 Acquiring facts
2 Appreciating a passage
3 Drawing inferences
4 Acquiring facts
5 Drawing inferences
6 Speed of reading easy material

[a]Source of data: D. L. Adler, A study of intelligence as manifested in perception of relationships. Unpublished master's thesis, University of Iowa, 1936.

With respect to comprehension in reading, Feder found that the factual-information tests loaded on a factor different from the inference tests. The variance of the appreciation test was associated most closely with that of the inference test; and the speed-of-comprehension test appeared to measure functions different from those measured by the other tests. In short, Feder concluded that the tasks of answering factual questions and of making inferences call to a considerable extent on quite different fundamental skills in comprehension. It is likely that this conclusion would have been reinforced had he included the nonchance unique variance of the test scores in his analysis.

The second factor-analysis study to be considered was carried out by Gans (1940). Her study was designed principally to find out whether recognition of the usefulness of reference materials in accomplishing a purpose already established for and recognized by pupils in grades 4-6 is related to general reading comprehension as measured by a composite of several published tests. She found that the variables were related, but to such a small degree that existing reading-comprehension tests could not effectively be used to locate pupils able to identify certain designated properties of reference materials. She performed a centroid factor analysis

of the common variance of ten skills in judging reference materials plus skills of general comprehension in reading. Five factors were obtained; these were graphically rotated in two groups of three factors to oblique solutions. The correlations among the oblique axes were not reported. She interpreted Factor I as the reading-ability factor (though the reading-criterion scores had the eighth lowest positive loading on it). The second factor was interpreted rather narrowly as the ability to detect relevancy or irrelevancy (as reference material) of designated sentences. Factors III and V could not be interpreted. Factor IV is said to differentiate between ability to accept the remotely relevant and to reject the fanciful in reference materials. The present writer does not have Dr. Gans's intimate knowledge of the functions presumably measured by the items that she wrote and administered; this may account for his inability to interpret the factors in a socially useful way. The data in the study do suggest, however, that among the skills of comprehension in reading used by middle-grade pupils are (a) ability to keep the purpose of reading constantly in mind; (b) ability to judge the relevancy of materials to that purpose; (c) ability to judge the truthfulness of statements made; and (d) ability to identify a writer's purpose.

Langsam (1941) obtained the intercorrelations of 21 variables judged relevant to the basic elements of which the reading process is composed in a sample of 100 girls in an entering class at Hunter College. She performed a centroid factor analysis of the common variance of these variables and obtained five factors. These were rotated graphically "so that the coordinate axes became meaningful." Langsam interpreted these factors as follows:

I. Verbal ability (V);
II. Perceptual ability (P);
III. Word fluency (W);
IV. Number facility (N);
V. Seeing relationships.

Alternative explanations of the functions measured might be:

I. Verbal reasoning;
II. Speed of mental operation;
III. Word knowledge;
IV. Quantitative reasoning;
V. (Not interpretable).

It seems safe to conclude that the paragraph-reading and other verbal tests included among Langsam's variables measure uncorrelated common factors of verbal reasoning ability and word knowledge. In addition, speed of mental operation in both verbal and nonverbal tests may have been found to be

present along with a quantitative reasoning ability that displayed itself mainly in three quantitative (or largely non-verbal) subtests of the American Council on Education Psychological Examination.

Conant (1942) constructed tests to measure the six skills in comprehension listed as variables 1-6 in footnote a to Table 5. She administered these specially prepared tests to 256 pupils in grades 10-12 in a suburban community judged representative of upper-middle-class residential areas along with the two published tests (that yielded four part scores) also listed in footnote a to Table 5. The intercorrelations of the 10 variables and their estimated reliability coefficients are shown in Tables 5 and 6.

The results of a principal-axis component analysis of the total variance of the ten variables expressed in standard measures is shown in Table 7. Conant interpreted the first component as a measure of general comprehension. Perhaps it might better be termed Word Knowledge. The second factor was interpreted by Conant as specific to the ACE Quantitative Score. It could be regarded more generally as Quantitative Facility, a combination of computational accuracy and quantitative reasoning ability. Conant interprets Factor III as a measure of linguistic ability or vocabulary. The present writer (keeping in mind the fact that the coefficients being interpreted have had the influence of preceding components partialed out) would suggest that it measures ability to apprehend the main thought or concept of a passage or problem independent of level of vocabulary. Conant did not interpret the remaining components.

In general, the data confirm the usual finding that word knowledge (or, more broadly, verbal facility) constitutes a very important fundamental element of comprehension in reading. They also show that the variance of tests comprising arithmetic problems expressed in verbal form is made up largely of verbal and quantitative reasoning ability plus numerical facility. The battery of tests did not permit a separation of computational and quantitative reasoning skills. Since the data can be used to calculate the component-score reliability coefficients, it would be interesting to obtain these statistics and to identify and interpret components with reliabilities significantly greater than zero at the .05 level.

In 1939, Davis (1941) examined the results of subjective analyses of comprehension, a few of which have been mentioned in this paper. Of these, special consideration was given to the analysis by Richards (1929). Davis made a subjective cluster analysis of the scores of skills mentioned by various investigators as part of the comprehension process in reading all sorts of materials. He then identified

TABLE 5

INTERCORRELATIONS OF SCORES REPORTED BY CONANT[a]
(N = 256)[b]

Variable	1	2	3	4	5	6	7	8	9	10
1	--	.7268	.5464	.6850	.6845	.7191	.5862	.6370	.5946	.5123
2	.7268	--	.8423	.7720	.8664	.7832	.6690	.7204	.6469	.5182
3	.5464	.8423	--	.6716	.7458	.7311	.6888	.6557	.6828	.5146
4	.6850	.7720	.6716	--	.7131	.9391	.6588	.7359	.6377	.5278
5	.6845	.8664	.7458	.7131	--	.7495	.7125	.6781	.6244	.5267
6	.7191	.7832	.7311	.9391	.7495	--	.7677	.7754	.7471	.5479
7	.5862	.6690	.6888	.6588	.7125	.7677	--	.7438	.7674	.5086
8	.6370	.7204	.6557	.7359	.6781	.7754	.7438	--	.7011	.5069
9	.5946	.6469	.6828	.6377	.6244	.7471	.7674	.7011	--	.5427
10	.5123	.5182	.5146	.5278	.5267	.5479	.5086	.5069	.5427	--

[a]Conant (1942, p. 87). The ten variables are as follows:

1. Main points in a passage;
2. Specific facts in a passage;
3. Organization of specific facts in a passage;
4. Cause-and-effect relationships in a passage;
5. Inferences from a passage;
6. Word knowledge;
7. Nelson-Denny Vocabulary Test;
8. Nelson-Denny Paragraph-Reading Test;
9. Linguistic Score, American Council on Education Psychological Examination;
10. Quantitative Score, American Council on Education Psychological Examination.

[b]The 256 cases were distributed as follows:

Grade 10, 69;
Grade 11, 72;
Grade 12, 115.

TABLE 6

ESTIMATED RELIABILITY COEFFICIENTS OF VARIABLES 1-6
USED IN CONANT'S ANALYSIS
(N = 256)

Variable	Estimated reliability coefficient
1	.64
2	.84
3	.85
4	.85
5	.79
6	.91

TABLE 7

DIRECTION COSINES AND VARIANCES FOR SIX PRINCIPAL
COMPONENTS OF CONANT'S MATRIX

Variable	I	II	III	IV	V	VI	VII-X
			Components				
1	.7941	-.0285	.3451	.2763	.3745	-.1068	
2	.9013	-.2054	.1949	-.2209	.0219	.0048	
3	.8444	-.1066	-.0619	-.4194	-.1079	-.1279	
4	.8777	-.1178	.1206	.2498	-.3378	-.0638	
5	.8712	-.1507	.1637	-.2265	.1217	.1437	
6	.9271	-.0819	-.0155	.2111	-.2125	-.1005	
7	.8457	.0401	-.3692	.0026	.1352	.1250	
8	.8528	.0291	-.1790	.1775	-.0125	.3533	
9	.8245	.1634	-.3770	.0363	.1459	-.2842	
10	.6630	.7005	.2168	-.1006	-.0924	.0597	
			Component Variances				
	7.1065	.6175	.5601	.5022	.3748	.2874	.0552

what seemed to be the core concept or concepts in each cluster and arranged these to form an outline of important skills in comprehension that are brought into play by mature readers (Davis, 1941, pp. 22-23); that is, readers who, given plenty of time, are able to decode satisfactorily the symbols represented by words. This outline is shown in Table 8.

If these skills were to be measured in a practical way in American schools, the economics of measurement (reflected in the need for low-cost test booklets and low-cost scoring and reporting procedures) dictated the use of objectively scorable measuring instruments. Of the latter, multiple-choice items appeared to provide maximum flexibility. Consequently, it was necessary to select from the outline of skills only those capable of objective measurement in group testing with the use of reusable test booklets and separate answer sheets. This caused points F3 and G to be left unmeasured. The remaining topics were grouped into nine categories, as indicated by the numbers in parentheses that follow them in the outline. These nine skills were given labels as shown in Table 9.

Items to measure them were then constructed for inclusion in Form Q of the Cooperative Reading Comprehension Tests (Davis et al., 1940), Test C1 (grades 7-9) and Test C2 (grade 10 through college). All the 543 entering freshmen in the Connecticut State Teachers Colleges and in two of the Massachusetts State Teachers Colleges took Tests C1 and C2 in September and October of 1940 with unlimited time and directions to mark what they thought were the best answers to all items. It turned out that 421 of them did so; for these students, scores in the nine skills were obtained by differential scoring. The details of the study are given elsewhere (Davis, 1941, 1944). Here it suffices to say that a principal-axis component analysis was performed on the matrix of obtained-score variances and covariances of the nine skill scores. The direction cosines for each of the nine variables that define each of nine components are shown in Table 10.

Application of an F-ratio test to successive pairs of the component variances (Kelley, 1944) showed that the components would appear in the same order in a very large proportion of every hundred replications of the process when the same items were administered to random samples of 421 pupils drawn from the same population. Estimation of the reliability coefficients of component raw scores by the method proposed by Davis (1945) showed that the scores in components I, II, III, VII, and VIII have reliability coefficients significantly different from zero (in a two-tail test) at the .05 level.

Inspection of the direction cosines for these five components, which we may be reasonably sure measure something

TABLE 8

OUTLINE OF IMPORTANT SKILLS OF COMPREHENSION AMONG MATURE READERS

	Davis number[a]	Bloom number[b]
I. Word knowledge--recognition vocabulary	(1)	(1.11)
II. Determining the meanings of words from contextual clues		
A. Meanings selected to harmonize with the content	(2)	(2.10)
B. Meanings determined by		
1. Figures of speech	(8)	(2.10)
2. Tone of the writer	(8)	(2.10)
III. Organizing meanings		
A. Connecting preceding thought with present and oncoming thought		
1. Looking ahead; anticipating next statements	(7)	(4.20)
2. Finding antecedents of words and phrases in the selection	(3)	(4.20)
B. Giving each element its appropriate weight	(6)	(2.20)
IV. Construing the writer's meaning		
A. Determining the central thought	(4)	(2.10)
B. Understanding statements from the passage which support the central thought	(5)	(2.10)
C. Understanding new statements which support the central thought	(6)	(2.20)
V. Drawing conclusions from the content		
A. Making interpretations not stated in the passage	(7)	(2.30)
B. Determining the writer's tone	(8)	(--)
C. Determining the writer's intent	(9)	(4.30)
D. Determining the writer's point of view	(9)	(4.30)
E. Recognizing the methods used in developing the passage	(8)	(--)
F. Evaluating the thought content		
1. Determining the degree of logical consistency	(6)	(6.10)
2. Weighing the accuracy and adequacy of the writer's conclusions	(6)	(6.20)
3. Considering the reliability of the evidence		(6.20)
G. Generalizing by applying the writer's conclusions to different situations		(2.40)

[a]Davis (1941, pp. 22-23).
[b]Bloom et al. (1956).

TABLE 9

NINE OPERATIONAL SKILLS OF COMPREHENSION IN READING AMONG MATURE READERS[a]

Variable	Description
1	Word knowledge, as measured by recognition vocabulary items
2	Ability to select the appropriate meaning for a word or phrase in the light of its particular contextual setting
3	Ability to follow the organization of a passage and to identify antecedents and find references in the passage
4	Ability to select the main thought of a passage
5	Ability to answer questions which are answered directly in the passage
6	Ability to answer questions which are answered in the passage but not in the words in which the question is asked
7	Ability to draw inferences from the passage about the content of the passage
8	Ability to recognize the literary devices used in a passage and to apprehend its tone and mood
9	Ability to determine the writer's purpose, intent, and point of view; i.e., to draw inferences about the author

[a]Davis (1941, p. 23).

TABLE 10

DIRECTION COSINES FOR NINE SKILL SCORES THAT YIELD NINE PRINCIPAL COMPONENTS[a]

Skills	I	II	III	IV	V	VI	VII	VIII	IX	Variance
					Components					
1	.813	-.571	-.064	-.033	-.082	.006	-.016	.001	.011	134.699
2	.184	.124	-.005	-.003	.971	-.019	-.017	-.028	-.076	10.563
3	.057	.054	-.001	.000	-.000	.000	.997	.000	-.004	3.009
4	.027	.048	-.000	.000	.067	.000	.000	.000	.996	1.220
5	.107	.149	.152	-.003	-.022	.970	-.014	-.024	-.012	6.050
6	.341	.469	.567	-.531	-.129	-.204	-.044	-.001	-.023	32.169
7	.336	.580	-.719	.008	-.147	-.020	-.051	-.091	-.028	33.752
8	.078	.105	-.001	.141	-.000	.000	-.010	.981	-.007	3.456
9	.233	.253	.366	.835	-.080	-.126	-.027	-.166	-.013	16.540
					Component Variances					
	192.270	22.824	8.657	5.282	3.828	3.306	2.327	1.956	1.006	241.457

[a]Davis (1944, p. 190). The skills are defined in Table 9.

other than chance, suggests that brief descriptions of what they measure are:

I. Knowledge of word meanings;
II. Reasoning in reading;
III. Concentration on literal sense meaning (without consideration of implications);
VII. Following the structure of a passage;
VIII. Recognizing the mood and literary techniques of a writer.

The remaining components measure mostly chance variance and perhaps specific nuggets of nonchance variance associated with each of four original variables--tests 9, 2, 5, and 4.

Davis' study points to the general conclusion that comprehension among mature readers is not a unitary ability but that it is largely dependent on knowledge of word meanings and on ability to reason in verbal terms. Other more specific skills are involved but to a small extent. If word knowledge and ability to reason in reading are measured together by test items that do not strongly emphasize one or the other of these two variables, and if the unique nonchance elements in reading skills are ignored, it is not difficult to reconcile the results of Davis' study and those of other studies that have been interpreted to indicate that comprehension in reading is a unitary ability.

One of these was reported by Harris (1948), who investigated the comprehension of literature. He found that the common variance of scores measuring comprehension of seven different passages could be explained by one factor. Variation of content from one passage to another did not generate additional factors. In a separate group of 106 men he obtained scores on seven skills judged important in understanding literature. Again, the common variance of these variables could be fully explained by one factor, which might be regarded as general verbal facility.

Hunt (1952, 1957) reported a study of 204 multiple-choice items drawn from available forms of the Cooperative Reading Comprehension Test. Twenty-one judges classified the items in terms of six of the nine skills originally used by Davis (1941). Each skill was represented by 34 items. In a sample of 370 examinees, Hunt obtained from the Flanagan Table approximations to the biserial correlation coefficients between individual item scores (1 or 0) on each of the 204 items and total scores on each of the six skills.

To eliminate the degree of self-correlation that occurs whenever scores on a given item are correlated with scores on a test that includes the item, Hunt corrected such

coefficients to obtain an estimate of what the coefficient would have been had that item not been included in the total score. This would be the correlation of scores on one item with total scores on 33 items. In addition, these corrected estimates and all of the other coefficients (between scores on items and scores on tests in which the items were not included) were corrected for attenuation resulting from the unreliability of the total scores.

The average of the twice-corrected coefficients between each of the 34 items and the test in which it was included was then obtained for each of the six types of items. Next, the average of the corrected coefficients between each of the 34 items in each test and total scores on each of the five tests in which it was not included was obtained. When the averages were compared, it was found that only the vocabulary items correlated significantly more closely (on the average) with the total score representing their type of skill (vocabulary) than with total scores representing the five other skills. This result may be regarded as evidence that all six types of items measure much the same general ability. It also suggests that there is some element of comprehension in vocabulary items that is not present in the other types of items. It is not surprising that tiny components of variance unique to certain types of items might be lost in approximation procedures used in the item analysis and in the corrections for self-correlation and for attenuation, particularly since the former may have been somewhat inappropriate according to Davis (1958).

Alshan (1964) investigated the skills in comprehension by making a principal-components analysis of the intercorrelations of item scores. He computed the product-moment intercorrelations of the first 40 items in Form 2A of the Davis Reading Test (Davis & Davis, 1962) in a sample of 527 pupils in grade 11. The 40 items constituted the first scale of the test and included items classified by skill, as shown in Table 11. Alshan performed a principal-axis component analysis of the matrix of phi coefficients and rotated the five components having the largest variances. The loadings of the items on these five components did not fall into a pattern suggesting that the items group themselves by type. Instead, the unrotated component loadings and variances suggest that one common element and chance account for the data. Whether this truly reflects the structure of basic abilities or skills underlying comprehension, as measured by these items, is difficult to determine. Tests of component stability and reliability of component scores were not applied, partly because the necessary data pertaining to item reliability could not be obtained.

Alshan has considered a number of influences on the data:

TABLE 11

COMPREHENSION SKILLS MEASURED BY DAVIS READING TEST[a]

Variable	Description	Number of items used by Alshan
1	Finding answers to questions explicitly or in paraphrase in a passage	8
2	Weaving together the ideas of a passage and grasping its central thought	12
3	Making inferences about the content of a passage and about the purpose or point of view of its author	13
4	Recognizing the tone, mood, and literary devices used in a passage	3
5	Following the structure of a passage	4

[a]Davis and Davis (1962, p. 5).

1. the low reliability coefficients variables (individual items);
2. the fact the phi coefficients reflect item difficulty as well as degree of item intercorrelation and reliability;
3. the small numbers of items per skill.

By and large, from this study we can only conclude that all of the items must measure to a considerable extent one major element in comprehension, probably general verbal facility.

In connection with their substrata analysis of reading in high school, Holmes and Singer (1966) performed a centroid analysis of the common variance of 56 variables administered to a sample of 400 pupils in grades 9-12 of the University of California Summer Demonstration School of 1953. Nine factors were obtained and rotated by the normalized Varimax procedure. The largest factor (which accounted for about 27 percent of the common variance of the 56 variables) appears to measure general verbal facility. The three recognition-vocabulary tests, the listening-comprehension test, the range-of-information test, the level-of-comprehension test, and the speed-of-comprehension test largely determine this factor.

The rotated factor having the second largest variance is irrelevant to comprehension in reading. It appears to measure a tendency to report personal problems of maladjustment.

The factor having the third largest variance (and listed as number 5) is, after reflection, a music aptitude and appreciation factor that has a faint correlation with comprehension in reading. The factor having the fourth largest variance (listed as number 4) appears (after reflection) to measure a verbal-perception ability. The fifth-largest variance is shown by a factor listed as number 6, which probably measures speed of mental operation or tendency to move as rapidly as possible in taking tests. The sixth-largest variance belongs with an interest factor defined by high mechanical, outdoor, and science interests and low clerical and personal-relations interests. It is irrelevant to comprehension in reading.

The three remaining factors are also irrelevant to comprehension in reading. Two of them are bipolar interest factors and the third is not clearly defined enough to warrant interpretation.

Probably the most striking feature of this analysis is that only two factors are relevant to the functions measured by the criterion tests of speed of comprehension and level of comprehension in reading. These two factors apparently measure a general verbal facility and speed of mental operation. Although Holmes and Singer (1966, pp. 134-135) hypothesized that interest-test scores and measures of school adjustment and personal problems would have substantial loadings on factors important to "speed and power" of reading, these expectations were not realized.

In addition to the factor analysis based on the intercorrelations of scores obtained by the 400 pupils in grades 9-12, Holmes and Singer (1966, p. 149) reported the results of similar analyses based on subsamples of boys (N = 211); girls (N = 189); "fast" readers (N = 108); "slow" readers (N = 108); high-level-of-comprehension readers (N = 108); and low-level-of-comprehension readers (N = 108). By and large, the differences in important factor loadings from group to group were small and may be attributable to chance or to factors of selection in forming the groups.

Davis has subjected to principal-components analysis two separate intercorrelation matrixes obtained in his uniqueness study of skills in comprehension (Davis, 1967, 1968). The results of his study are reported earlier in this paper. The intercorrelations were obtained by administering Forms C and D of a specially constructed paragraph-comprehension test without time limit on successive days to a large number of twelfth-grade pupils in academic high schools. Each form included 12 items measuring each of 8 skills, which are listed in Table 3. There were no overlapping items in Forms C and D. Eight scores were obtained from each form; thus, each pupil had 16 separate scores. The intercorrelations of these scores form two separate matrixes of across-day

intercorrelations. Matrix CD includes the correlations of scores C1 with D2, D3, . . . , D8; C2 with D3, D4, . . . , D8; etc. Matrix DC includes the correlations of scores D1 with C2, C3, . . . , C8; D2 with C3, C4, . . . , C8; etc. The number of cases in each matrix is 988, which is large enough to provide highly stable results.

The unrotated component loadings (product-moment correlation coefficients between each initial variable and each of the eight unrotated components) are shown in Tables 12 and 13. The corresponding elements of the eigenvectors of the two matrixes were used with equivalent-forms reliability coefficients of the eight reading skills to estimate reliability coefficients of scores in each of the eight unrotated components of each matrix. These coefficients are shown in Tables 14 and 15.

Unrotated components that displayed reliability coefficients that were both positive and significantly different from zero at the .05 level, or better, were rotated to the normalized varimax criterion. The loadings of the five rotated components for each of the two matrixes are shown in Table 16.* Comparison of these two sets of loadings shows that factors CD-III and DC-II measure knowledge of word meanings (Skill 1). Factors CD-II and DC-III measure recognition of a writer's purpose, attitude, tone, and mood (Skill 5). Factors CD-IV and DC-I measure primarily a combination of two skills: weaving together ideas in the content to attain understanding and drawing inferences from the content (Skills 3 and 4). Introspection by skilled readers and previous data have suggested that these two skills differ in that weaving ideas seems to be a deductive process while drawing inferences seems to involve inductive reasoning. The mental ability measured by factors CD-IV and DC-I is apparently a reasoning ability that underlies both deductive and inductive processes. It will be noted that in the analysis based on matrix DC, Skill 8 (following the structure of a passage) shows its heaviest loading on factor DC-I. Factors CD-V and DC-V appear clearly

---

*The principal-component analysis, computation of component-score reliability coefficients, and rotation to the normalized varimax-criterion were accomplished with a program written by Miss Frances S. Byers, a doctoral student in evaluation and research at the Graduate School of Education, University of Pennsylvania. The program first tested, by means of Bartlett's test of sphericity, the significance of the difference between each obtained intercorrelation matrix and a matrix of true intercorrelations of zero. Given the nature of the variables measured in the study and the very large numbers of cases, the results (as expected) showed negligible probability that either matrix of obtained correlations could have arisen by chance if the population values were zero.

TABLE 12

PRODUCT-MOMENT CORRELATION COEFFICIENTS BETWEEN INITIAL VARIABLES AND PRINCIPAL COMPONENTS IN MATRIX CD
(N = 988)

Vari-able	I	II	III	IV	V	VI	VII	VIII	v
1	.747	-.045	.611	-.137	-.128	-.088	.088	-.129	1.000
2	.821	-.050	-.054	-.053	.517	-.014	-.011	-.224	1.000
3	.800	-.141	-.224	.365	-.249	-.077	.060	-.292	1.000
4	.826	-.117	.086	.186	.026	.472	.084	.179	1.000
5	.764	-.518	-.124	-.190	-.048	-.166	-.144	.215	1.000
6	.798	.313	.084	.323	.092	-.260	-.073	.269	1.000
7	.805	.306	-.094	-.218	-.155	.144	-.386	-.088	1.000
8	.797	.230	-.252	-.297	-.079	-.039	.383	.073	1.000
v	5.057	.550	.529	.466	.387	.354	.341	.317	8.000

TABLE 13

PRODUCT-MOMENT CORRELATION COEFFICIENTS BETWEEN INITIAL VARIABLES AND PRINCIPAL COMPONENTS IN MATRIX DC
(N = 988)

Vari-able	I	II	III	IV	V	VI	VII	VIII	v
1	.660	.707	.019	.221	-.024	-.095	-.038	-.064	1.000
2	.795	.131	-.044	-.424	-.343	.214	.043	-.059	1.000
3	.804	-.198	-.378	-.041	-.033	-.381	-.022	-.154	1.000
4	.826	-.090	-.174	.081	.276	.336	-.273	-.098	1.000
5	.771	-.303	.317	.317	-.315	.006	-.077	-.091	1.000
6	.810	-.040	.354	-.183	.334	-.079	.205	-.152	1.000
7	.869	-.015	.123	-.137	.051	-.160	-.215	.370	1.000
8	.843	-.070	-.200	.215	.018	.142	.373	.197	1.000
v	5.112	.663	.457	.436	.409	.365	.311	.248	8.000

TABLE 14

EQUIVALENT-FORMS RELIABILITY COEFFICIENTS OF INITIAL SCORES AND OF COMPONENT SCORES IN MATRIX CD

Variable	Reliability coefficient*	Component	Reliability coefficient*
1	.58	I	.93
2	.64	II	.31
3	.63	III	.24
4	.64	IV	.23
5	.59	V	.06
6	.63	VI	-.03
7	.67	VII	.02
8	.68	VIII	-.18

TABLE 15

EQUIVALENT-FORMS RELIABILITY COEFFICIENTS OF INITIAL SCORES AND OF COMPONENT SCORES IN MATRIX DC

Variable	Reliability coefficient*	Component	Reliability coefficient*
1	.58	I	.93
2	.64	II	.38
3	.63	III	.18
4	.64	IV	.14
5	.59	V	.08
6	.63	VI	.01
7	.67	VII	-.09
8	.68	VIII	-.38

*The standard error of a correlation coefficient of zero with N = 988 is .0318. Hence, an obtained coefficient of ±.0623 is significantly different from zero at the .05 level.

TABLE 16

FACTOR LOADINGS OF INITIAL VARIABLES AFTER ROTATION TO NORMALIZED VARIMAX CRITERION OF FIVE COMPONENTS THAT HAVE POSITIVE RELIABILITY COEFFICIENTS SIGNIFICANT AT THE .05 LEVEL
(After reflection of certain factors and rearrangement in matching order)

Matrix CD

Variable	III	II	IV	V	I	v
1	.883	.224	.207	.178	.253	
2	.201	.319	.244	.802	.323	
3	.113	.420	.786	.105	.295	
4	.377	.342	.541	.360	.238	
5	.238	.816	.231	.243	.265	
6	.327	-.072	.647	.428	.375	
7	.287	.160	.300	.190	.767	
8	.143	.271	.231	.252	.797	
v	1.241	1.216	1.628	1.156	1.747	6.988

Matrix DC

Variable	II	III	I	V	IV	v
1	.922	.118	.212	.199	.193	
2	.246	.196	.306	.828	.267	
3	.082	.205	.780	.377	.179	
4	.227	.174	.714	.117	.444	
5	.128	.872	.315	.197	.266	
6	.185	.233	.290	.220	.841	
7	.241	.304	.421	.397	.553	
8	.300	.356	.704	.181	.237	
v	1.167	1.159	2.113	1.159	1.478	7.076

to measure the ability to get the literal sense meaning of details in a passage (Skill 2).

Factors CD-I and DC-IV do not appear to measure the same mental abilities. CD-I is mainly determined by scores in Skills 7 and 8 (Identifying a writer's technique and Following the structure of a passage) whereas DC-IV is largely determined by scores in Skill 6 (Drawing inferences about the meaning of a word from context). The fact that slightly different results were obtained from analyses of matrixes of intercorrelations based on the administration of carefully designed equivalent forms to a very large sample of high-school seniors shows how careful research workers must be in the interpretation of studies using techniques of factor analysis. The data carry an implication that the rigorous procedures employed in this study for deciding how many principal components should be interpreted and rotated to the normalized varimax criterion should specify consideration only of principal components that yield scores having reliability coefficients significantly different from zero at a more stringent level than the .05 level specified in advance in this study. The .01 level should, perhaps, be adopted. The danger of setting a stringent requirement is, of course, the added likelihood of making Type-II errors in circumstances where the development of hypotheses for investigation may be the primary objective of the research.

The results of this factorial analysis confirm Factors I, II, and III of Davis' previous study (Davis, 1941, 1944) and incorporate Factors V, VII, and VIII of that study in two additional factors, identified above as CD-I and DC-IV.

MODELS OF COMPREHENSION

Chapman's Three Models of Comprehension

Chapman (1969) has described what she regards as three theories of comprehension in reading:

1. The uncorrelated, or isolated, skills theory, which postulates that comprehension is made up of a set of skills (or mental processes) that are learned and used independently, and in any order.

She illustrates her conception of comprehension by a hypothetical matrix of intercorrelations among four tests of uncorrelated skills, as follows:

Test	A	B	C	D
A	1	0	0	0
B	0	1	0	0
C	0	0	1	0
D	0	0	0	1

2. The global-skill theory, which postulates that comprehension is a unitary ability that, in combination with errors of measurement alone, accounts for all of the variance of measurements of comprehension in reading.

Chapman's illustration of a hypothetical matrix of intercorrelations of tests of four skills of the type envisaged by this model follows:

Test	A	B	C	D
A	1.00	.90	.90	.90
B	.90	1.00	.90	.90
C	.90	.90	1.00	.90
D	.90	.90	.90	1.00

3. The hierarchical skills theory, which postulates that comprehension is made up of separate but correlated skills and that these differ in complexity because the more complex include all or parts of the simpler, or more basic, ones.

Chapman has illustrated the intercorrelations among skills of this type in the following hypothetical matrix of the relationships among four tests that increase in complexity from A to E:

Test	A	B	C	D	E
A	1.00	.71	.58	.62	.44
B	.71	1.00	.81	.71	.63
C	.58	.81	1.00	.87	.78
D	.62	.71	.87	1.00	.89
E	.44	.63	.78	.89	1.00

Consideration of these theories in the light of accumulated data indicates that the uncorrelated, or isolated, skills theory must be rejected. Evidence regarding the intercorrelations of scores on tests of comprehension skills, particularly that provided by Davis (1941, 1944, 1967, 1968), shows that tests measuring a wide variety of skills involved in comprehension are positively and, in most instances, closely correlated.

The global-skill theory must also be rejected since proper correction for attenuation will not cause all of the intercorrelations of a set of well-constructed skill tests to become unity. A residual of varying size of unique nonchance

variance will remain in most tests. Table 3 shows the percent of the original nonchance variance of each skill test that is unique in the set of eight tests used by Davis (1968, p. 541). The rejection of the global-skill theory is not out of harmony with the results of factor analyses that have shown that the common variance of a set of skill tests can often be explained by one factor (Thurstone, 1946). The global-skill theory must take into account nonchance unique variance as well as error variance that skill tests in any given set have in common with others in the set being considered. The fact that the addition or withdrawal of one or more skill tests to or from a set may determine whether certain skills are common or unique nonchance elements of the total variance of a set of tests shows how shaky is the logical foundation for factor analyses of common variance alone.

The hierarchical skills theory can be reconciled with the experimental findings concerning the intercorrelations of skill tests in reading comprehension. These findings, however, do not require that hierarchies be established in the sense that certain complex skills cannot be learned or performed unless a specified skill or specified skills have previously been mastered. The experimental findings permit but do not require this situation.

Inspection of the intercorrelations in Davis' cross-day matrixes (Davis, 1968, p. 524) based on scores of 988 twelfth-grade students in academic high schools shows no marked evidence that the eight skill tests (which display approximately equal reliability coefficients) can be arranged in a clear-cut order of cumulative agglomeration of simple skills in more complex skills. More systematic investigation of this point needs to be made.

Logical considerations suggest that certain of the eight skills are more basic than others. For example, knowledge of word meanings appears, *a priori*, to be essential for comprehension. For this reason, Davis (1941) presented the intercorrelations of skills 2-9 shown in Table 9 with the influence of skill 1 (Word Knowledge) partialed out of skills 2-9. As expected, the partial coefficients were much lower than the zero-order coefficients, so Davis inferred that knowledge of word meanings is a basic ability in which level of competence exerts great influence on all other skills in comprehension.

Davis' 1941 Model of Comprehension

In *Fundamental Factors of Comprehension in Reading*, Davis (1941) postulated that much of the variance of each of nine tests of skills in comprehension would be found to be overlapping and that a smaller number of variables (orthogonal

principal components), representing basic mental abilities, would be found to account for a large proportion of the variance of the trait defined as comprehension. The skills that Davis used to define comprehension are shown in Table 8. The elements of the nine eigenvectors that resulted from a principal-components analysis and the corresponding eigenvalues are shown in Table 10. Of these, Davis (1944, p. 194) reported that five yield scores having reliability coefficients significantly different from zero at the .05 level (in a two-tailed test).

Davis' model, which postulated that the trait defined as comprehension may be represented as a weighted composite of uncorrelated basic mental abilities obtained by principal-components analysis, is different from Chapman's independent-skills theory, which postulates that scores on tests measuring different skills used in comprehension will be uncorrelated or only slightly correlated (Chapman, 1969).

By 1944, then, Davis' 1941 model of comprehension had been tested empirically and it had been found, at a rather high level of probability, that at least five uncorrelated basic mental abilities were needed to explain the nature of the trait labeled comprehension in reading. Tentative identifications of these abilities appear earlier in this paper. Verification of the essentials of Davis' 1941 study were confirmed by a more elaborate investigation (Davis, 1968). The five basic mental abilities account for about 94 percent of the variance of the trait (as shown in Table 10), but the first two alone account for 89 percent. Hence, Davis (1942) provided scoring keys for obtaining individual scores in uncorrelated Components I and II and a Profile Chart on which these scores could be plotted in comparable units (Cooperative Test Service Scaled Scores). Since these materials antedated the ready availability of computer scoring by a quarter of a century, they were used very little because of the practical difficulty of obtaining scores. Davis (1942) also reported the correlations of Components I and II with Quantitative and Linguistic scores on the American Council on Education Psychological Examination and total scores on the Nelson-Denny Reading Test in samples of college freshmen. The results, shown in Table 17, after correction for attenuation to facilitate interpretation, indicate that Component I performs as would be expected of a measure of word knowledge. If, as its composition strongly suggests, Component II is a measure of reasoning in reading (independent of word knowledge), we must conclude that this basic mental ability has little in common with the types of items that determine the Quantitative scores on the American Council on Education Psychological Examination. It will be noted that the Q and L scores on the examination correlated to the extent of .58 in the sample of 121 cases. The negative coefficient between scores on Component II and total scores on the Nelson-Denny Reading Test may very well

TABLE 17

PRODUCT-MOMENT INTERCORRELATIONS OF SCORES IN COMPONENTS I AND II AND SELECTED VARIABLES, AFTER CORRECTION FOR ATTENUATION

	(N = 121)				(N = 82)
	1	2	3	4	5
1. Component I[a]	-	.08	.41	.89	.86
2. Component II[b]		-	.13	.07	-.23
3. Q score, ACEPE			-	.58	-
4. L score, ACEPE				-	-
5. Total, N-D Reading					-

[a]Component I was identified as Knowledge of Word Meanings.
[b]Component II was identified as Reasoning in Reading.

be characteristic of correlations of scores on Component II and scores on conventional tests of silent reading. The latter often include vocabulary items in their total scores and make use of paragraph-comprehension items that appear to measure largely knowledge of word meanings. Further research is needed to evaluate the meaning of the basic mental abilities resulting from Davis' component analyses. In practice, these abilities are measured pari passu by Forms Q-Z of the Cooperative Reading Comprehension Tests or Forms A-D of the Davis Reading Tests.

NEXT STEPS NEEDED IN RESEARCH ON COMPREHENSION

1. Davis' model, which has been tested empirically at the high-school and college-freshman levels, should be modified appropriately and tested, separately, in grades 2-4 and 5-9. Both principal-component and uniqueness analyses should be used.

2. Controlled experiments should be conducted to determine the effect on comprehension of various types of reading materials that are produced by teaching the operational skills that represent five or more of the abilities that have been shown to underlie comprehension (Davis, 1941, 1968). The design of these experiments should be such as to permit estimates of the relative effectiveness of training in each separate skill on: (a) performance in that skill; and (b) performance in overall comprehension. Appropriate learning exercises will have to be devised (probably in specially

prepared workbooks) for teaching purposes in each of three or four preselected grades.

3. Controlled experiments should be conducted to determine the effect on overall comprehension of different "orders" (or hierarchies) in which operational skills that represent five or more basic mental abilities are taught and practiced. The same learning exercises mentioned above may be adapted for this purpose in carefully defined and guided teaching programs.

4. A survey study should be conducted to determine the extent to which the development of comprehension skills in silent reading of materials commonly read in and out of school by American children aged 7-18 is affected by:

(a) cultural level of their homes;
(b) level of oral word knowledge;
(c) level of accuracy and fluency of oral reading;
(d) level of short-term memory for ideas that they see and hear;
(e) level of capability for weaving together ideas that they hear and can understand.

At present, teachers and research workers in the field of reading quite literally do not know what proportion of American school children perform below the average child at each age or grade level in silent-reading comprehension as a result of having:

(a) below-average skills in decoding the words that they encounter;
(b) below-average knowledge of the meanings of words that they hear or knowledge of the names of things that they see pictured;
(c) below-average skills in remembering ideas that they hear and understand;
(d) below-average capability for weaving together ideas that they hear and understand.

Lack of adequate information about these matters is especially troublesome in planning improved programs for teaching reading to children from culturally deprived homes and communities. More broadly, the lack of information has led to inability to define reading retardation and reading disability in meaningful terms that are logical and can be widely accepted.

Carefully planned sampling techniques and the use of specially prepared materials for individual interviews with trained personnel would make a survey in grades 2, 5, 8, and 11 possible with the expenditure of smaller amounts of time and money than are now devoted to mass testing programs that often make use of inappropriate tests that are likely to be maladministered and misinterpreted.

REFERENCES

Adler, D. L. A study of intelligence as manifested in perception of relationships. Unpublished master's thesis, University of Iowa, 1936.

Albright, B. F. Typical reading disabilities of college entrants. Unpublished master's thesis, University of Southern California, 1927.

Alshan, L. M. A factor-analytic study of items used in the measurement of some fundamental factors of reading comprehension. Unpublished doctoral dissertation, Teachers College, Columbia University, 1964.

Barrett, T. C. Taxonomy of cognitive and affective dimensions of reading comprehension. In H. M. Robinson (Ed.), Innovation and change in reading instruction. Chicago: University of Chicago Press, 1968. Pp. 19-23. (Sixty-seventh yearbook of the National Society for the Study of Education)

Barton, W. A. Outlining as a study procedure. New York: Bureau of Publications, Teachers College, Columbia University, 1930.

Berry, B. T. Improving freshman reading habits. English Journal, College Edition, 1931, 20, 824-828.

Bloom, B. S., et al. Taxonomy of educational objectives. Handbook 1: Cognitive domain. New York: McKay, 1956.

Carroll, J. B. Review of Holmes and Singer, Speed and power of reading in high school. Research on the Teaching of English, 1968, 2, 172-184.

Carroll, R. P. An experimental study of comprehension in reading. New York: Bureau of Publications, Teachers College, Columbia University, 1927.

Chapman, C. A. An analysis of three theories of the relationships among reading-comprehension skills. Symposium on psycholinguistics and reading presented at the meeting of the International Reading Association, Kansas City, May, 1969.

Cleland, D. L. A construct of comprehension. In J. A. Figurel (Ed.), Reading and inquiry. Newark, Del.: International Reading Association, 1965. (Conference Proceedings, Vol. 10)

Conant, M. M. The construction of a diagnostic reading test. New York: Bureau of Publications, Teachers College, Columbia University, 1942.

Davis, F. B., et al. Cooperative reading comprehension test, Tests C1 and C2, Form Q. New York: Cooperative Test Service, 1940.

Davis, F. B. Fundamental factors of comprehension in reading. Unpublished doctoral dissertation, Harvard University, 1941.

Davis, F. B. Two new measures of reading ability. Journal of Educational Psychology, 1942, 33, 365-372.

Davis, F. B. Fundamental factors of comprehension in reading. Psychometrika, 1944, 9, 185-197.

Davis, F. B. The reliability of component scores. Psychometrika, 1945, 10, 57-60.

Davis, F. B. A brief comment on Thurstone's note on a reanalysis of Davis' reading tests. Psychometrika, 1946, 4, 249-255.

Davis, F. B. (Ed.) The A.A.F. qualifying examination. Washington, D.C.: U.S. Government Printing Office, 1947.

Davis, F. B. A note on part-whole correlation. Journal of Educational Psychology, 1958, 69, 77-79.

Davis, F. B. Identification and classroom behavior of gifted elementary-school children. In The gifted student. Washington, D.C.: U.S. Government Printing Office, 1960. Pp. 19-32.

Davis, F. B. Identification and measurement of reading skills of high-school students. Philadelphia: University of Pennsylvania, 1967. (Cooperative Research Project, No. 3023)

Davis, F. B. Research in comprehension in reading. Reading Research Quarterly, 1968, 4, 499-545.

Davis, F. B., & Davis, C. C. The Davis reading tests, Series 1 and 2, Forms A, B, C, D. New York: Psychological Corporation, 1962.

Duker, S. Applicability of the substrata-theory to reading in the elementary school. Elementary English, 1964, 41, 921-924.

Dvorak, A., & Van Wagenen, M. J. Diagnostic examination of silent reading abilities. Minneapolis: M. J. Van Wagenen, 1939.

Eurich, A. C. Minnesota speed of reading test for college students. Minneapolis: University of Minnesota Press, 1936.

Feder, D. D. Comprehension maturity tests--a new technique in mental measurement. Journal of Educational Psychology, 1938, 29, 597-606.

Flanagan, J. C. Flanagan aptitude classification tests: Technical report. Chicago: Science Research Associates, 1959.

Gagné, R. M. The conditions of learning. New York: Holt, Rinehart, & Winston, 1965.

Gans, R. A study of critical reading comprehension in the intermediate grades. New York: Bureau of Publications, Teachers College, Columbia University, 1940.

Gates, A. I. A study of the role of visual perception, intelligence, and certain associative processes in reading and spelling. Journal of Educational Psychology, 1926, 17, 433-445.

Gates, A. I. Gates silent reading tests. New York: Bureau of Publications, Teachers College, Columbia University, 1927.

Gates, A. I. The improvement of reading. New York: Macmillan, 1935.

Gates, A. I. Gates reading survey. New York: Bureau of Publications, Teachers College, 1953, 1958.

Gephart, W. J. Application of the convergence technique to basic studies of the reading process. Bloomington, Ind.: Phi Delta Kappa, 1970.

Gray, W. S. Principles of method in teaching reading as derived from scientific investigation. In National Society for the Study of Education, Eighteenth Yearbook, Part II. Bloomington, Ill.: Public School Publishing Co., 1919. Pp. 26-51.

Gray, W. S. The major aspects of reading. In H. M. Robinson (Ed.), Sequential development of reading abilities. Chicago: University of Chicago Press, 1960. Pp. 8-24. (Supplementary Educational Monographs, No. 90)

Hackett, M. G. A hierarchy of skills in listening comprehension and reading comprehension. (Doctoral dissertation, University of California, Berkeley) Ann Arbor, Mich.: University Microfilms, 1968. No. 69-14900.

Harris, C. W. Measurement of comprehension in literature. The School Review, 1948, 56, 280-289; 332-342.

Hilliard, G. H. Probable types of difficulties underlying low scores in comprehension tests. University of Iowa

studies in Education II, No. 6. Princeton, N. J.: Psychological Review Co., 1924.

Holmes, J. A. Factors underlying major reading disabilities at the college level. Unpublished doctoral dissertation, University of California, Berkeley, 1948.

Holmes, J. A. Factors underlying major reading disabilities at the college level. Genetic Psychology Monographs, 1954, 49, 3-95.

Holmes, J. A., & Singer, H. Speed and power of reading in high school. Washington, D.C.: U.S. Government Printing Office, 1966. (Cooperative Research Monograph, No. 14)

Horning, F. M. A diagnostic study of difficulties in reading comprehension. Unpublished master's thesis, University of Southern California, 1927.

Horst, A. P. Psychological measurement and prediction. Belmont, Calif.: Wadsworth Publishing Co., 1966.

Hunt, L. C., Jr. A further study of certain factors associated with reading comprehension. Unpublished doctoral dissertation, Syracuse University, 1952.

Hunt, L. C., Jr. Can we measure specific factors associated with reading comprehension? Journal of Educational Research, 1957, 51, 161-171.

Irion, T. W. H. Comprehension difficulties of ninth-grade students in the study of literature. New York: Bureau of Publications, Teachers College, Columbia University, 1925.

Jacobson, M. D., Stimart, R. D., & Wren, G. T. Models and educational research. American Educational Research Journal, 1971, 8, 311-320.

Kelley, T. L. Essential traits of mental life. Cambridge: Harvard University Press, 1935.

Kelley, T. L. A variance-ratio test of the uniqueness of principal-axis components as they exist at any stage of the Kelley iterative process for their determination. Psychometrika, 1944, 9, 199-200.

Kingston, A. L. A conceptual model of reading comprehension. In E. P. Bliesmer & A. J. Kingston (Eds.), Phases of college and other reading programs. Milwaukee: National Reading Conference, 1961. Pp. 100-107.

Knapp, R. P., Stoker, H. W., & Bashaw, W. L. Validation of the taxonomy of educational objectives. Journal of Experimental Education, 1966, 34, 69-76.

Lachman, R. The model in theory construction. Psychological Review, 1960, 67, 113-129.

Langsam, R. S. A factorial analysis of reading ability. Journal of Experimental Education, 1941, 10, 57-63.

Levine, R. L., & Hunter, J. E. Statistical and psychometric inference in principal-components analysis. Multivariate Behavioral Research, 1971, 6, 105-116.

Maccia, E. The model in theorizing and research. In A. J. Kingston (Ed.), The use of theoretical models in research in reading. Newark, Del.: International Reading Association, 1966. Pp. 6-17.

Plessas, G. P. A critique of the substrata-factor theory of reading. Elementary School Journal, 1964, 64, 218-225.

Pressey, L. W., & Pressey, S. L. A critical study of the concept of silent reading. Journal of Educational Psychology, 1921, 12, 25-31.

Raygor, A. Problems in the substrata-factor theory. Reading Research Quarterly, 1966, 1, 147-150.

Richards, I. A. Practical criticism. New York: Harcourt Brace, 1929.

Robinson, H. M. The major aspects of reading. In H. A. Robinson (Ed.), Reading: Seventy-five years of progress. Chicago: University of Chicago Press, 1966. Pp. 22-32. (Supplementary Educational Monographs, No. 96)

Shaycoft, M. F. What the tests measure. In J. C. Flanagan, F. B. Davis, et al., The American high school student. Pittsburgh: Project TALENT Office, University of Pittsburgh, 1964.

Singer, H. A developmental model of speed of reading in grades 3 through 6. Reading Research Quarterly, 1965, 1, 29-49.

Singer, H. Reply to John Carroll's comments on the Holmes-Singer monograph and on the substrata-factor theory of reading. Research in the Teaching of English, 1969, 3, 87-102.

Smith, D. E. P. Reading comprehension: A proposed model. In O. R. Causey & E. P. Bliesmer (Eds.), Ninth yearbook of the National Reading Conference for colleges and adults. Fort Worth: Texas Christian University Press, 1960. Pp. 21-27.

Spache, G. D. What is comprehension? In E. P. Bliesmer & R. C. Staiger (Eds.), Problems, programs, and projects in college-adult reading. Milwaukee: National Reading Conference, 1962. Pp. 17-19.

Spache, G. D. Toward better reading. Champaign, Ill.: Garrard Publishing Co., 1963.

Spache, G. D. The substrata-factor theory of reading--its design and statistics. Elementary English, 1964, 41, 915-920.

Sparks, J. N., & Mitzel, H. E. A reaction to Holmes's basic assumptions underlying the substrata-factor theory of learning. Reading Research Quarterly, 1966, 1, 137-145.

Strang, R. Problems in the improvement of reading in high school and college. Lancaster, Pa.: Science Press Publishing Co., 1938.

Thorndike, E. L. The psychology of thinking in the case of reading. Psychological Review, 1917, 24, 220-234. (a)

Thorndike, E. L. Reading as reasoning: A study of mistakes in paragraph reading. Journal of Educational Psychology, 1917, 8, 323-332. (b)

Thorndike, E. L. The understanding of sentences. Elementary School Journal, 1917, 18, 98-114. (c)

Thurstone, L. L. Note on a reanalysis of Davis' reading tests. Psychometrika, 1946, 11, 185-188.

Van Wagenen, M. J. Diagnostic examination of silent reading abilities: Rate of comprehension, Part I, Form B. Junior Division. Minneapolis: Educational Test Bureau, 1953.

Wark, D. M. Substrata-factor theory--a dissenting view. In G. B. Schick & M. May (Eds.), New frontiers in college-adult reading. Milwaukee: National Reading Conference, 1966.

Wherry, R. J. A new formula for predicting the shrinkage of the coefficient of multiple correlation. Annals of Mathematical Statistics, 1931, 2, 440-457.

Wherry, R. J. Test selection and suppressor variables. Psychometrika, 1946, 11, 239-247.

Yoakum, G. A. Reading and study. New York: Macmillan, 1928.

DISJUNCTIVE CATEGORIES IN EPHEMERAL MODELS

Albert J. Kingston

The University of Georgia

The word "model" is one of today's most popular words. Unfortunately, the word is so loosely used as to cause confusion even though its purpose is to clarify (Kingston, 1965). Reading is not the only discipline in which the word is used to describe different behaviors. The term "model" is loosely employed in education, psychology, sociology, and even the physical sciences. A number of so-called models have been developed to explain reading behavior. Among them is a substrata factor model, a psycholinguistic model, some linguistic models, as well as learning and perception models (Singer, 1970). Typically, these models of reading are labeled partial models. A partial model implies that the inventor of the model recognizes that the model describes only a few kinds of reading behavior. Most models of reading come equipped with flow charts or circuit diagrams which resemble electrical wiring diagrams or PERT charts. Few, if any, of the models provide either operational or functional definitions, and so far as I can determine, none present important concepts in mathematical terms. Finally, few, if any, of the current reading models lend themselves to empirical verification or can be used to predict reading behavior (Kingston, 1970).

One genuine problem faced by those who build reading models lies in the lack of adequate reading theory (Kingston, 1968a, 1968b). Again, there seems to be some difference in opinion concerning the relationship of model to theory and *vice versa*. Some seem to employ the words as synonyms which can be freely interchanged. Others believe that an adequate theory must precede model building. Still others appear to believe that modeling, particularly the development of partial models, leads to better theory because models help explain complex processes. Brodbeck (1959) has stressed that the practice of using the term "model" as a synonym for theory is redundant and unnecessary. Perhaps a major source of this confusion stems from the fairly common usage by researchers of terms like "statistical model" or "design model" to identify experimental treatments. One can only hope that model makers will avoid confounding the two terms in the future.

Yet a model obviously has an intimate relationship to a theory. One widely accepted use of a model is to facilitate research and to test theory. Brodbeck (1959) states:

> Two theories whose laws have the same form are isomorphic or structurally similar to each other. If the laws of one theory have the same form as the laws of another theory, then one may be said to be a model for the other [p. 379].

This use of "model" implies that a theoretician might employ a more adequate theory as a model for explicating a phenomenon that was less understood (Maccia, 1966). Thus for years the structure of the molecule was likened to our solar system. If either communication theory or information theory were highly developed, one or both could be said to be models of the reading process. Unfortunately, the reading process and information theory do not appear to be isomorphic.

One also can argue that if a model or partial model does indeed serve to explicate a complex phenomenon, it also may serve to help a theoretician to develop a more adequate theory. Hopefully, theories are not science fiction, nor are they just made up without reference to reality. The theory must be rooted in known facts and accumulated scientific evidence. The fact that much reading research seems to have little or no relationship to theory bothers many students of reading and should bother more (Weaver, 1969). Any model or partial model which serves to help its inventor or others to organize evidence in such a way that the development of logical postulates or axioms is facilitated can only serve to improve our research. Probably none would argue that improved research questions and adequate hypotheses would inevitably result.

The use of models in theorizing and research is fraught with dangers. Often the model bears little resemblance to the phenomenon it supposedly represents. Most reading models are described as "partial models"; i.e., models which represent only limited aspects of reading or the reading behavior of merely certain classes of readers. One can, quite correctly, ask the question: What relationship does the model have to the reading process as commonly seen? The variation among so-called partial reading models attests to the diversity in background and interests of those concerned with reading. Language acquisition and utilization models, psycholinguistic models, information-theory models, perceptual models, learning models represent disjunctive categories. There is an urgent need to bridge these categories or to unite them in a logical manner. Right now it is doubtful if an Aristotle would understand the cumulative effect of these models. Certainly, they fail to help us understand the complexities of the reading process. Rather the situation is reminiscent of the story of the blind men who sought to describe an elephant from the particular parts they touched. Before we plunge pellmell into researching the current models, there is an urgent need for further synthesis and logical analysis.

The language employed to describe reading behavior continues to trouble theoreticians and researchers (Carroll, 1964; Gephart, 1970; Kingston, 1969a, 1969b). Too often, the terms employed are vague and are neither functional nor operational. Unfortunately, models of reading based upon language, perception, cognition, and learning all have problems with terminology. Often the reading specialist who becomes entranced in studying these disciplines finds he merely has improved his vocabulary. Too often, vocabulary improvement and the cerebral stimulation that accompanies the study of a new discipline is mistaken for a feeling that one is moving closer to the desired goal of insight and understanding. Cynics might even be so unkind as to point out that the same disciplines attract attention because of the greater abstraction of the terms they utilize. What reading needs is not more abstract definitions but less abstract definitions. Hayakawa (1941) employed the following example to illustrate an inadequate definition:

> Kangaroo. Where the biologist would say "herbivorous mammal, a marsupial of the family macropodidae," ordinary people say "Kangaroo."

Such a definition merely tells us how various people describe the same thing. It tells us little more than we knew before we started. Reading specialists will find that although those in other disciplines employ different words to describe the inputting of words, they too have not cracked the ubiquitous "black box." Someone should search through all reading models to try to determine what actually is known.

It is difficult to understand why so many theoreticians have not reexamined the commonly accepted parameters of reading. While all model makers seem to recognize that the reading behavior of young naive readers is different from that of adults, the progression of change is rarely recognized in the models created. School teachers, of course, long have recognized that primary-grade children function differently from older children or adults not only in reading but intellectually, socially, emotionally, and physically as well. Which models throw more light on these differences? Reading is commonly regarded as a thought process (Thorndike, 1917). What does this mean? Are there differences between thought when reading and when not reading? How can we best teach thinking? Is it best taught in nonreading situations? One could continue to list any number of pertinent questions of this type. The point here, however, is that in the last two or three decades reading behavior seems to have expanded to include many human functions. It would be interesting to see models built on more restrictive parameters.

In conclusion, it must be stressed that any model should be based on psychological reality. The writer believes

he could develop a model of reading (partial, of course) based upon the ingestion and digestion of a food such as cornflakes. The cornflakes might represent language. The model includes the teeth (vocabulary?), mouth (the larger, the greater the input), the gullet (communication channel), stomach (capacity? How about coining the term SQ?). Liver, bile, and pancreas could be called previous learning, emotions, and drives. The intestines and colon either serve to assimilate or reject (Can the colon be the site of critical reading?). Such a model could be expanded to include most of the important dimensions of the reading process. But do they serve any real purpose? For those concerned with reading behavior, it should be obvious that any model we develop must be empirically testable.

REFERENCES

Brodbeck, M. Models, meaning, and theories. In L. Gross (Ed.), Symposium on sociological theory. Evanston, Ill.: Row & Peterson, 1959. Pp. 373-403.

Carroll, J. B. The analysis of reading instruction: Perspectives from psychology and linguistics. In E. R. Hilgard (Ed.), Theories of learning and instruction. Chicago: National Society for the Study of Education, 1964. Pp. 336-353.

Gephart, W. J. Application of the convergence technique to basic studies of the reading process. Bloomington, Ind.: Phi Delta Kappa, 1970.

Hayakawa, S. Language in action. New York: Harcourt, Brace, & Co., 1941.

Kingston, A. J. The use of models in research in reading. In J. A. Figurel (Ed.), Reading and inquiry. Newark, Del.: International Reading Association, 1965. Pp. 348-349.

Kingston, A. J. Psychological embarrassments of reading. In G. B. Schick & M. M. May (Eds.), Multidisciplinary aspects of college-adult reading. Madison, Wis.: National Reading Conference, 1968. Pp. 4-9. (a)

Kingston, A. J. The psychology of reading. In J. A. Figurel (Ed.), Forging ahead in reading. Newark, Del.: International Reading Association, 1968. Pp. 425-432. (b)

Kingston, A. J. Areas of confusion in the development of a science of reading. In G. B. Schick & M. M. May (Eds.), The psychology of reading behavior. Madison, Wis.: National Reading Conference, 1969. Pp. 113-116.

Kingston, A. J. Reactions to theoretical models of reading: Implications for teaching and research. In H. Singer &

R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 183-186.

Maccia, E. The model in theorizing and research. In A. J. Kingston (Ed.), The use of theoretical models in research in reading. Newark, Del.: International Reading Association, 1966. Pp. 6-17.

Singer, H. Theoretical models of reading: Implications for teaching and research. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes in reading. Newark, Del.: International Reading Association, 1970. Pp. 147-182.

Thorndike, E. L. Reading as reasoning: A study of mistakes in paragraph reading. Journal of Educational Psychology, 1917, 8, 323-332.

Weaver, W. W. The contribution of research to reading theory. Journal of Reading Behavior, 1969, 1, 3-18.

9-66|8-67

SOME MODELS OF THE READING PROCESS: LEARNERS AND SKILLED READERS

Jane F. Mackworth

Stanford University

DEFINITIONS OF READING

The word "reading" can only be defined in terms of "who is reading what in what state for what reason." We read in order to obtain information, but the actual process of reading is the coding of visual symbols into words according to a fixed system. The words are spoken aloud to and by a beginning reader. Later vocalization becomes internal and may disappear altogether. The total act of reading involves almost the whole human brain, for we get out of reading very largely what we bring to it. A deaf child reading a simple text, perhaps articulating the words but not hearing them, is acting quite differently from a skilled adult scanning a textbook at high speeds to find some special fact. A bored and inattentive mother who is reading aloud a familiar story to her child and simultaneously planning tomorrow's menu falls in yet another category. It is even possible to read a foreign language, if the rules of pronunciation are known, without the slightest understanding of what is being read.

We have, therefore, a range of definitions of reading, from the simple definition as a decoding process to the most complex process involving all past experience. Crosby and Liston (1968) have presented a model of reading in three stages of skill. The child, they say, learns to decode the written signs into speech and only understands what he has read when he hears himself say it. The adult suppresses the overt motor activity and goes straight from the motor-speech cortex (subvocal speech) to the sensory-speech area, and so to comprehension. The third stage of skilled reading suppresses verbalization, and goes straight from visual perception to comprehension of meaning.

Holmes (1970) tells us that

> Reading is an audio-visual verbal processing skill of symbolic reasoning, sustained by the interfacilitation of an intricate hierarchy of substrata factors that have been mobilized as a psychological working system and

> pressed into service in accordance with the purposes of the reader [pp. 187-188].

He defines substrata factors as neurological subsystems of brain cell-assemblies, which gain an interfacilitation by firing in phase. Kling (1966) has demonstrated that the substrata-factor theory can be related isomorphically with general open-systems theory, which deals with organized complexity in the whole range of sciences. Kling identifies eight postulates that are common to the two theories. Of these eight, three will be particularly considered in this paper: (a) Exchange of energy, information (or matter), with the environment through input and output channels; (b) Dynamic interplay of the subsystems; and (c) Feedback processes.

Fitts (1964) pointed out that the processes which underlie language behavior are very similar to those which underlie skilled motor performance. Both are information-processing activities guided by some general plan or program, as discussed by Miller, Galanter, and Pribram (1960). Such activities are hierarchical in nature, and emphasis is laid on the intrinsic coherence of stimulus and response sequences. Limitations are imposed by the capacities for discrimination and memory. Fitts' model includes the concepts of coding, feedback, memory, and adaptive processes leading to self-improvement. Reading and language use the whole of the brain, although dyslexia only arises in adults when the specific language or visual areas are damaged. The higher levels of meaning would seem to be generalized throughout the brain, as suggested by Pribram (1969b) in his theory of the hologram, discussed later.

Goodman (1970) has defined reading as a psycholinguistic guessing game, a selective process that involves partial use of available language cues selected from the perceptual input on the basis of the reader's expectation, an interaction between thought and language. Efficient reading, he tells us, results from skill in selecting the fewest, most productive cues necessary to produce guesses that are right the first time. The importance of the neural model of the incoming stimuli, with its associated plan or program, has received the attention of an increasing number of neurophysiologists, as they discovered that brain waves (evoked potentials and background activity) reflected psychological factors such as expectancy, attention, and learning, together with other physiological changes found in the orienting response, which result in a heightened state of sensitivity. Reed (1970) approaches the problem of definition from the other end, and suggests that the basic act of reading is the identification of linguistic forms from strings of written configurations that represent them, as evidenced by producing the conventional signs for the <u>same</u> linguistic form in some other system of representation (e.g., speech). He distinguishes this

process from understanding, which involves the identification of the meaning of these linguistic forms. This definition of reading is similar to the definition presented by Crosby and Liston (1968), that reading is translating graphic symbols into sound according to a recognized system. Neisser (1967) says that reading is the process on the sensory-verbal dimension, whereby "the sensory input is transformed, elaborated, stored, recovered and used [p. 4]."

DEVELOPMENTAL ASPECTS

Syntheses of Meaning, Speaking, and Reading

While reading is a visual-verbal process, it is the third stage in three levels of synthesis that have been achieved by the growing child. The first stage is the development of meaning. The newborn infant is assailed through all his senses by an onrush of data that are almost totally meaningless for him. Gradually, he learns to take this information from his senses and build it into coherent models which allow him to react efficiently to his environment. He learns to know that certain sensations imply a satisfaction of certain needs, and so his environment gradually acquires meaning for him, both in terms of his immediate needs and also in terms of expectancies; that is, the ability to predict what will happen next, and be prepared for it. These internal models that combine the data from all his senses constitute meaning. Gradually, he will extend these highly concrete meanings into increasingly abstract ones at the same time that he is refining his models into more specific identifications, recognizing the difference between his mother and other women, or between his furry toy and cats that may scratch.

The second level of synthesis is involved in the acquisition of language. This is a three-way synthesis between certain sounds, both those that he makes, and those that others make, feedback from his speech motor system (articulatory muscles), and meaning. Liberman et al. (1967) have demonstrated that the identification of spoken words depends on parallel processing of the speech motor programs. The ear perceives in sequence, and the phonemic rate of speech is too great for the resolving power of the ear. The information contained in speech is encoded by using the different parts of the speech tract in parallel, and is decoded by referring the incoming speech sounds to the commands that are sent by the brain to the articulatory muscles.

The third level of synthesis is reading, probably the simplest of the three and yet the one that gives the most difficulty. Is this because these sounds of speech are a genetic characteristic of man, while the visual-verbal code of reading

is not, and must be painfully acquired by each succeeding generation? Here there is again a three-way synthesis between the spatial signs, the spoken word, and meaning. Again, there is a parallel processing of input, this time visual, followed by the sequential verbal processing.

The primary task for the normal child in learning to read is to learn the rules necessary to transform the spatial signs into verbal equivalents, either as overt or as subvocal speech, followed by the linking of the written material to meaning. Memory is an essential part of this activity at all levels. If I say to a blind person, "The grass is green," no information is conveyed, except perhaps that grass has some property in common with other objects that are also called "green." All considerations of language and reading come back ultimately to the messages that have reached us from the outside world through our senses. Otherwise, the verbal medium is conveying only nonsense. While reading is basically a coding process, its important aspect, like language and other codes, is the relation between these codes and the primary sense data from meaningful objects. In considering the teaching of reading, it is important to include a knowledge of the sense data that the child has already transformed into internal models. Words have meaning for him only when he has already encountered the objects to which they refer. CAT means cat only when he is familiar with a cat. Bay (1963) has pointed out that adult aphasics usually show deficient concept formation and also have inadequate internal models of objects and people. Their attempts to reproduce objects or people by drawing or modeling may be grossly defective in essential parts.

Affective Aspects

Attention

Included in meaning we may also consider the affective aspect of the material and the environment of learning (Athey, 1970; Briggs, 1969). Interest in the subject matter is a vital aspect of reading. This brings us to the central position of attention in reading. The physiological aspect of affect and attention is arousal. A child who is too aroused may be quite unable to attend to his task; he is too preoccupied thinking of his problems, fear, hunger, anger, excitement, and so on. Too little arousal is even worse. A drowsy uninterested child is not going to learn anything. The child who is interested and alert is the child who has "all systems go"; he is ready and anxious to learn.

The best learner is one who is not only in a suitable physiological state of alertness, but is also ready to direct his attention towards the task in hand. Pribram (1969b, 1970)

has pointed out the importance of the nerves that run from the associative areas of the cortex to the lower parts of the brain and to the sensory regions and motor fibers that direct the gaze and other muscles used in the task. The outgoing nerves play a dual role in attention. One set runs from the frontal region of the cortex, and produces concentration upon the stimulus, thus localizing attention. The other set runs from the inferotemporal regions, via the reticular system in the brain stem, and produces a generalized state of alertness, which reduces the background noise in the brain. We can read with very little attention when we know how to read; but to learn and remember, attention is needed. The capacity or amount of attention appears to be limited, so that at any given level of arousal there is only a certain amount of attention available. This channel capacity must be focused on the task in order to produce the best input and learning (J. Mackworth, 1963a, 1963b, 1964, 1966, 1969, 1970).

When a new, interesting or unexpected stimulus is presented, the process of orientation occurs. This involves both directing the gaze towards the stimulus, and also an increase in the general level of alertness and sensitivity. Once the stimulus has been identified, and a decision made that it is unimportant, then habituation occurs. This is the opposite of orientation. The gaze turns away from the stimulus, and the general level of alertness may be reduced. Unfortunately, this process may occur with any monotonous stimulus, even though we may consciously wish to pay attention, and reading is no exception. It becomes just as difficult to pay attention to something being read as it is to pay attention to someone talking, if the subject matter is not greatly interesting. Habituation is an essential part of the brain mechanisms, because it frees the conscious level of attention for the important, unexpected, or dangerous stimuli.

E. Sokolov (1969) has for many years pointed out that these processes of orienting and habituation are the external and physiological concomitants of the formation of internal models of the environment. Experiments have shown that the neural trace produced by a repeated stimulus registers the intensity, duration, location in space, dimensions, qualitative features, and the temporal pattern of the stimuli as well as the general environment. (It might be pointed out that if the general environment of the school is not attractive, the child will connect the reading process with this dreary place, and lose all interest.) The neural model anticipates the future probability and meaning of the next stimulus. A neural mechanism checks the meaning and nature of an incoming stimulus against the predictions of the neural model. Thus construction of a neural model is an active process, involving a two-way exchange of messages from environment and brain, as Kling (1966) has pointed out.

Pribram (1969b) has discussed one possible way in which these models may be constructed in the brain. He has suggested that the incoming stimulus is represented in the brain by wave-fronts that carry an image by interference effects until it is stored in the long-term memory, which perhaps lies in the RNA molecules of the brain cells. Ribonucleic acid (RNA) is the cellular equivalent of the nuclear DNA (deoxyribonucleic acid) which carries the genetic memory (Hyden, 1970). Pribram (1969b) compared this temporary memory produced by a wave front of neural activity to the formation and reconstruction of a hologram, in which the whole image is contained at each point, and can be seen three-dimensionally. Amplitude and phase information about the wave front may be stored in parallel. While the neural pattern produces spatial coding (representation), the temporal factors are registered by attention, involving organization and rehearsal.

The construction of the neural model in a human brain usually involves the participation of the verbal content of the brain. Mackworth, Grandstaff, and Pribram (1971) have found that aphasic children with severe speech difficulties did not show habituation of the gaze to a novel item that remained on show for one minute. In this lack of habituation they differed even from two-year-old normal children, who looked away from the item after a quarter minute, in the same way as older children (Mackworth & Otto, 1970). All visual data that can be recognized must be stored in the brain, but the cue or category that allows us to find these data when they are required may often be verbal. Thus language difficulties interfere with recognition and storage of visual data. Thus unduly prolonged preoccupation with a novel item can result from language disability, even though language has no obvious relationship with the task.

Motivation

Motivation is a very important factor in learning or failing to learn to read. A discussion of this vital aspect of education is outside the scope of this paper, but it may be mentioned that Zigler (1966) has suggested that retardates and lower-class children may be so certain that they are going to fail that they are unable to pay attention to the task. Such children need specific reinforcement to perform at their maximum capacity. Almost any procedure may help a child who is accustomed to failure. When he is made to believe that the new procedure will cure his incapacity, he may change his expectancy from failure to success.

PROCESSES INVOLVED IN SKILLED READING

The following discussion is based on the model shown in Figure 1. This summary model of the reading process can be outlined as follows:

Parallel Processing: Visuo-Spatial

The visual input of the stimulus, during an eye fixation, lasts about 250 msecs. in skilled reading. This input is normally an active process involving selection, attention, expectancy and prediction.

Recognition of the input results from matching it with a memory trace, a generalized visual record of the word and its components in long-term memory. By recognition, the visual input is stabilized and generalized, and becomes the iconic image.

Iconic image. While there may be a primary sensory trace lasting for about 250 msecs. after the stimulus, the iconic image is believed to last for a second or longer. It is postulated to hold several inputs simultaneously, thus smoothing out the effect of a series of separate inputs. It lasts at least as long as the normal eye-voice span.

Acoustic Input

In learning to read, a child learns to match the written input to a spoken word, first pronounced by the teacher and later by himself. This matching gives meaning to the written word. Recognition of the spoken word involves the mediation of the articulatory system, presumably the motor speech neural patterns stored in the speech area. Later, the acoustic input disappears, and in skilled reading there is only the articulatory neural activity. This, too, may disappear in certain kinds of reading.

Coding and Memory

The words are coded from the iconic image into short-term memory (STM) by motor speech programs. Such programs will activate the matrix of acoustic and other sensory associations as well as verbal probabilities, giving rise to expectancies as to what will come next. Short-term memory may last for several seconds but is rapidly destroyed by incoming data. Material in STM is processed in various ways by feedback from long-term memory (LTM), and the processed data may be stored in LTM or forgotten. Meaning is stored in relation to all verbal levels, from the word, the sentence,

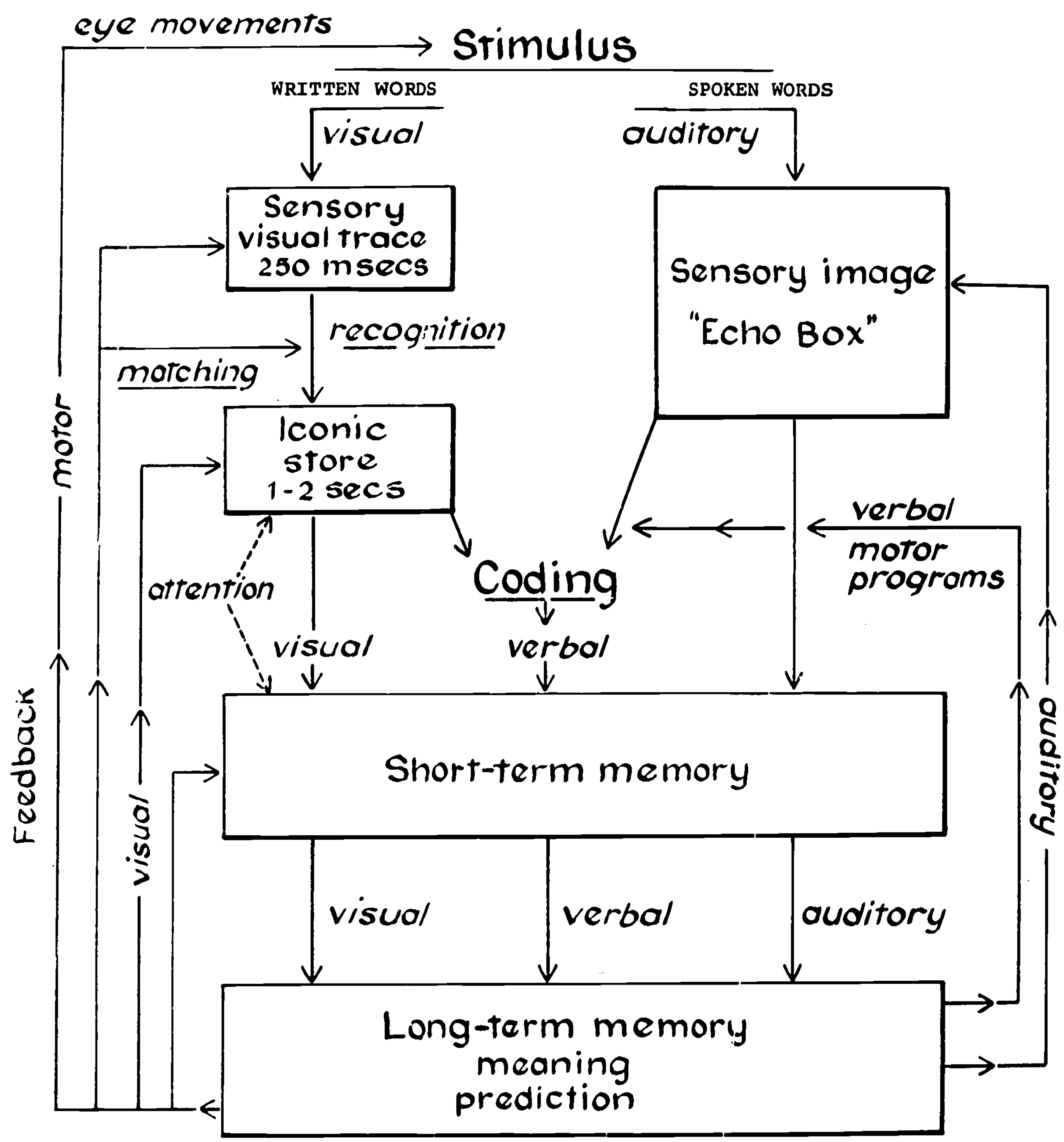


Fig. 1. Model of reading process.

and the paragraph to the book, and finally to syntheses of all data related to the input. At all levels, there is visual storage both of the input and related associations. Other sense data will also be included in the stored matrix.

STAGES OF VISUAL PROCESSING

Visual Sensory Trace

Most authors now recognize that there is a primary storage of the visual input in a visual form, but this primary store is very brief. It is believed that there are at least two stages of the visual record of the entire input from one fixation. The first is very brief, possibly even retinal, and appears to last only for a quarter of a second. It is masked by the next visual input. This we are calling the sensory visual trace. The second is the iconic image and results from the matching of the input with stored data; it lasts for a second or so. Since Cattell (1886) discovered that people could read several letters or even several words when these were presented for only 50-100 msecs., a great deal of work has been devoted to discovering the factors and nature of this initial image. It was originally known as the span of attention, being thought of in the same terms as the memory span. Sperling and his colleagues (Neisser, 1967, chapt. 2; Sperling, 1960) demonstrated that subjects could repeat any one of three lines of four letters each, when they were told immediately after the flash which line they were to repeat. They saw all the letters, but could not repeat them all because the trace faded so rapidly. Because he found that the trace could be masked by an interfering stimulus which occurred any time up to a quarter of a second after the information display, Sperling concluded that the duration of the visual image was a quarter of a second. The duration of an eye fixation during reading is usually about a quarter of a second in skilled reading. Such a period is long enough to allow the data from a single fixation to be processed before these data are destroyed by the next fixation.

Iconic Store

The term 'iconic store' was suggested by Neisser (1967). Geyer (1970) proposed that this term could be used for a visual store that resulted from the processing of the primary input. The primary visual store may be matched with a stored pattern, and as a result of this match a percept is formed that is both more stable and more simplified than the primary store. J. Mackworth (1962, 1963a, 1963b) estimated that there was a visual store that lasted for one to two seconds. This estimate was derived from the finding that subjects could repeat items correctly for about 1.5 seconds after

a brief exposure. The duration of correct report was not affected by the nature of the material, which consisted of digits, letters, or colors. The number of items recalled by name was, however, dependent on the material since digits were named faster and colors slower than letters. Thus, it appeared that the limitation on the number of items recalled was determined by the rate of verbal coding from an image with a fixed duration. This finding explained Cattell's observation that words could be reported as easily as separate letters. The limitation is not a perceptual one but a coding one, a word taking little longer to name than a single letter.

Posner and Keele (1967) also reported data indicating that the visual store could last up to a second or so. They compared the matching of two letters. Recently, Standing et al. (1969) have reported two different kinds of short-term visual storage, one lasting for 300 msecs. and one lasting for 900 msecs. The first was a process that became phenomenally discontinuous in time at intervals greater than 200-300 msecs. between flashes. The second involved the recognition of words; here the successive flashes summated over intervals of 500-900 msecs. to allow recognition from subliminal flashes. Again we see the difference between two kinds of visual storage: sensory and cognitive.

Cohen (1968) demonstrated that visual recognition or matching precedes verbal or semantic processes. She found that when subjects were comparing two words, they made a decision most rapidly (612 msecs.) when the two words were to be judged visually different. It took 678 msecs. to decide that the words were visually identical. Judging that the words were acoustically different took longer (842 msecs.) than that they were acoustically identical (716 msecs.). Semantic consideration took even longer. She concluded that there was parallel processing of other characteristics after visual matching. It takes longer to determine that two words are visually identical than to detect a difference because the whole word must be examined to be sure of identity. In a further experiment, Cohen (1969) studied the matching of consonants. She concluded that the visual comparison preceded the naming of the letter, since the comparison was slower when uppercase letters were compared with lowercase letters. Posner, Boies, Eichelman, & Taylor (1969) reported a similar result, but found that the advantage of the visual match was lost when the interval between the two members of the pair was greater than two seconds. They concluded that the iconic image remained available up to two seconds.

Posner and Konick (1966) demonstrated that visual memory of the position of a circle on a line could be retained by rehearsal over an interval but was rapidly destroyed by an interpolated task. This memory was clearly visual, showing no relation to verbal labels. Taylor and Reilly (1970) also

concluded that figural analysis of a visual stimulus occurs at an earlier stage of processing than does naming. They found that naming a letter took longer than recognizing it when it was shown visually and compared with a letter that was shown previously or spoken by E. In the latter case, S was apparently able to transform the spoken letter back to the visual form as efficiently as he could recall the visual form shown previously. Sales, Haber, and Cole (1969) found that accuracy of recall for a series of words with different vowel sounds was greater when the words were seen rather than heard, especially when the report itself was verbal. Therefore, they concluded that visual distinctive features are identified in the initial coding. Visual input produced errors that were not related to auditory confusions.

Neisser and Beller (1965) suggested that printed words are processed in two stages, "stimulus examination" and "memory examination," respectively. Stimulus examination entails the visual input and its comparison with stored visual representations of words. Words can be rejected very rapidly on the basis that they are different from the target, a known word. When the search is defined in terms of the meaning of a target, it takes much longer.

Kolers (1968) has demonstrated that the "recognition" of a word (visual match to stored pattern) involves the whole relationship of the letters in the word. The difficulty of reading text that had undergone various geometrical transformations was affected by the relation of the letters to the words. When the individual letters were reversed separately within a word so that the word could not be oriented to the stored word pattern by any whole transformation, the difficulty of reading the word was greater than when transformations that involved the word as a whole were used.

In some recent unpublished work, Grandstaff, Mackworth, and de la Pena have found that aphasic children with comprehension difficulties could reject simple visual shapes that did <u>not</u> match the sample just as fast as did the normals. But when the aphasics found the matching pattern, they took twice as long as the normals to decide that it was correct. They seemed to be able to discard unwanted material quite satisfactorily, but they were impaired in their use of the visual traces for the more detailed process of positive identification.

Models of Perceptual Processes

These data make it clear that visual recognition or matching a learned pattern with the input precedes verbal coding. Moreover, when the visual input is a word, the matching process is made between word and stored pattern, with

individual letters being scanned only incidentally. This is not to say that reading should be taught by the whole word method, for it is doubtful if the necessary details of the word patterns would be recorded properly so early in the learning process. To put material into memory store, conscious attention to the details is usually essential.

What is perceived is a resultant of the two processes: the sensory input and the comparison with the stored pattern. Because the stored pattern is an abstraction from a large number of somewhat similar patterns, the percept of the word is already shorn of many irrelevant details. Most sensory inputs are compared with neural models, recognized, categorized, and discarded before ever the percept reaches conscious awareness (J. Mackworth, 1969, 1970). Only the interesting, important, or unidentified reach the conscious level.

Geyer (1970) has suggested that the visual input is scanned at about 8 msecs. per element, and coded into the iconic store, where the percept is held for about one second. He points out that "organizational and associational processes" begin immediately after the visual intake and develop meaning, which continues to develop until "well after the processing of a given word is completed." The parallel processing that is believed to be characteristic of the early visual matching stage has been discussed in neurological terms by Spinelli (1970). He has suggested that the memory store must be content-addressable. All that is necessary is to provide the system with a fraction of the chunk of information required and the remainder will be played back. He postulates a nerve net in which the incoming sensory nerve is connected to the outgoing nerve cell by hundreds of interneurons. Both the input and the output cells are connected to a match cell, which also has an output axon. It is also possible to imagine that the long-term memory stores are intracellular molecules, which could be activated in parallel.

Sperling (1967, 1970) proposed a model which takes the visual input by a sequential scan directly into the "recognition buffer memory," which converts the visual image into a program of motor instructions and stores these instructions. He says, "The program for rehearsal of output can be set up in a very short time (e.g., 50 msecs. for three letters) compared to the time necessary to execute it (e.g., 500 msecs. for three letters)." This suggestion can be compared with the conclusion of Liberman et al. (1967) that understanding speech depends on a program of motor instructions to the speech muscles. However, we must remember that Liberman put forward his suggestion because he felt that the rate of information processing required by ordinary speech was too fast for the resolution by the acoustic system. Thus, it may be questioned whether the high rate of processing required by the tempo of ordinary speech can be speeded up tenfold as required by Sperling's model.

We can, however, find such a high rate of processing in the visual system, as shown by experiments on search (Cohen, 1970; Neisser & Beller, 1965). Sternberg (1967) has suggested that there are two operations in the recognition of a character. Operation 1 is the formation of the stimulus representation (visual sensory trace), and is carried out only once; Operation 2 is the comparison of the stimulus representation with the memory representation of a character (matching). This operation may occur once for each character. If, however, the letters form a word, the whole word may be matched in one operation. Sternberg points out that "what is represented in operation 2 are the physical properties of the stimulus" (rather than verbal coding). His data indicate a slope of about 40 msecs. per character, thus fulfilling the requirements of Sperling's coding, but being visual rather than verbal.

Wheeler (1970) discussed the finding that recognition of letters is more accurate when they occur in meaningful words than when they are shown tachistoscopically in a set of random letters. He presented three classes of models based on analysis of the task in terms of the extraction of features from the stimuli. He pointed out that word recognition cannot be analyzed into a set of independent recognition processes. Feature selection would cover the data if it were extended to include digrams with a frequency effect added. "At some level the aspects of the visual stimulus are processed simultaneously as a unit (i.e., in parallel)." Wheeler suggests that there is a "perceptual recognition unit," which may vary according to the material, from letters to phrases. This may correspond to the matching process suggested earlier by which the visual input is compared with long-term visual patterns and is thus generalized and stabilized. The other two models discussed by Wheeler are the discrimination net and the simultaneous-constraints model. In the latter model, there are two stages; first, there is a feature-extraction stage in which processing is in parallel; and second, the features are used to determine a code for the stimulus. This coding involves information loss.

The suggestion that expectancy and the ready availability of a template to match the stimulus are important aspects of perception was confirmed by the experiments of Aderman and Smith (1971). They presented letter strings tachistoscopically. Half of these strings were random and half were spelling patterns (Gibson, Pick, Osser, & Hammond, 1962). The spelling patterns were perceived more accurately if the subject knew that they would be seeing a spelling pattern, but if they did not know what kind of string they would be seeing, the spelling pattern was not perceived more accurately than the random-letter string. They suggested that the subjects decided beforehand how to segment the string; and when they saw it, they segmented it into the largest possible units

which were permitted by the expected organization, and which had representations in long-term memory. Since a nonsense word has no such representation, it would be treated as a spelling pattern. The spelling patterns must contain position information, since a spelling pattern depends on its position. A pseudo word is only pronounceable if its spelling patterns are in the same order as they occur in normal words (Gibson et al., 1962). The hypothesis that the memory storage of a spelling pattern includes its position within the word is similar to the hypothesis by Wickelgren (1969) that speech is encoded as "allophones," which include position information. The matter is discussed later in this paper.

Briefly, we may assume that the first visual trace has the function of holding the visual input long enough to activate a matching process between the input and a pattern stored in long-term memory. With such an assumption, we are no longer tied to such rapid requirements for the verbal coding. We may also note that, in normal reading, the only function of the first visual trace is to prevent any discontinuity in the observed stimulus. With each new fixation, the previous input will be erased from this first visual store. However, the previous input has now developed into the stabilized and generalized iconic image. It would seem probable that several inputs are held simultaneously in the iconic image, allowing context to be established. While the earlier inputs are fading, new ones are being added. Verbal coding can then proceed at a reasonable rate. Silent reading may well involve the verbal coding of only the more important words, thus increasing the speed of reading.

While the input probably continues on to the short-term memory and to the long-term memory in some generalized visual form, it also enters short-term memory as the coded verbal form. The exact nature of this coded form is under discussion, but it would appear to be a synthesis of visual, articulatory, and auditory forms, which are activated from long-term memory into short-term memory by the coding process. The whole process, from the very first visual matching to the final storage of hierarchically coded data, involves feedback between long-term memory and the input.

Short-Term Visual Memory

Before dealing with verbal or coded short-term memory, the further transformations and increasing durability of the visual record should be considered. While theoretical models of brain processes are necessarily represented in separate and isolated stages, the brain is in fact a network through which a neural impulse travels, activating an ever-increasing number of cells. Each stage of this flow lasts longer than the earlier stage. Such an effect can be seen in the evoked potential,

which is a record of a series of impulses passing beneath an electrode attached to the scalp. The first wave represents the first passage of the sensory stimulus, with a maximum about 100 msecs. after the stimulus. The later waves may continue until a decision has been reached and have been shown to represent the more cognitive aspects of the stimulus. Walter and his colleagues (Walter, 1969) have demonstrated an Expectancy Wave (or CNV) that fills the interval between a stimulus and another that is expected (J. Mackworth, 1969). It can be seen that these stores that we have postulated have objective reality in electrical changes in the brain.

We may think of a visual stimulus as continuing to activate neural currents in a spatial representation of the stimulus even after the verbal coding has been performed and verbal short-term memory has been activated. The importance of the visual content of memory has been pointed out by Paivio (1969):

> Imagery concreteness is the most potent stimulus attribute yet identified among meaningful items, while m (meaningfulness) and other relevant attributes are relatively ineffective. Imagery is a preferred mediator when at least one member of the pair (of words) is relatively concrete.

Paivio demonstrates that the improvement in perception and learning of items when they are meaningful is in fact related to the amount of imagery that they call up. Posner (1969) has emphasized in his model of long-term memory that both the visual and name records of a stimulus must be present. However, the visual store has undergone a process of abstraction, which retains the essential features and eliminates the minor variations that interfere with matching.

A number of workers have demonstrated that visual material is retained visually, even when the material to be remembered is one or more words. Visual-recognition memory is an important aspect of reading (Samuels, 1970). Visual-recognition memory is connected with reading ability, but not with intelligence. Samuels pointed out that children will discriminate between words with the minimum number of visual cues, using first letters as their preferred cue. Therefore, in order to encourage children to identify new words correctly, it is necessary to train them to discriminate among words by looking at the whole word. This can be done by requiring discrimination among words in which the second or later letters are different.

The importance of the visual aspects of a stimulus in relation to memory has been demonstrated by Turvey and Egan (1970). They presented trigrams (consonants with a particular vowel sound) which were written horizontally. Between the

stimulus and its recall there was an intervening task. They found that the trigrams were recalled more poorly in successive trials, an illustration of proactive inhibition. Each new trigram is confused with the one before it. Then they gave a test stimulus, which was either a trigram with a different vowel sound (phonemic change) or a trigram with the original vowel sound, but written vertically. They found that there was improvement in each case; recall of this novel stimulus was considerably improved by either phonemic or visual change. It is clear that interference was as much visual as phonemic. This test is also an interesting example of habituation and orientation with improvement of sensitivity to an unexpected stimulus.

Allen (1970) found that in paired-associate learning of words, there was greater interference between words which had similar spelling but different pronunciation than between words which rhymed but were spelled differently (e.g., door, more). He concluded that acoustic factors may not be important in discriminative memory, while formal (visual) similarity is important. Many other workers have found that, in short-term memory, there is a visual factor that is as important, or more important, than the verbal one (Fristoe & Blanton, 1970; Murdock, 1967, 1968; Rosenfeld, 1970). It can, therefore, be concluded that, even though visual material may be coded verbally, there is clearly a visual component that lasts for several seconds or longer.

Long-Term Visual Memory

In order to recognize a stimulus word, its visual representation must be present in long-term memory. Is the speech center the place where all verbal records are kept--visual, motor, and acoustic--or is there evidence that at least some verbal storage is elsewhere? Sperry and Gazzaniga (1967) found that patients with disconnection of the hemispheres could write meaningful material with the subordinate left hand, and they could select the correct object when its written name was shown to the left visual field. They reported that the minor hemisphere is unable to vocalize words, but can point to a written representation of a spoken word.

The speech center is usually in the left hemisphere, while the same areas in the right (nondominant) hemisphere are concerned with visual and auditory processes. Lansdell (1968) found that there was a direct correlation between the amount of destruction of the left temporal lobe and deficiencies in vocabulary. Patients with destruction of the right temporal lobe showed deficiencies in the visual task of closure, but there was no relation between the deficiency and the amount of brain tissue destroyed. Perhaps the storage of the motor

patterns of speech is very highly localized, but the visual patterns may have a more generalized representation in the brain. Butters, Barton, and Brody (1970) found that patients with impairment of the right parietal lobe showed impaired visuospatial comprehension, and difficulty in coding an auditory pattern. Patients with impairment of the left parietal lobe had marked dyslexia and cross-modal difficulties (Butters & Brody, 1968). Both groups of patients had short-term visual-memory deficits (Butters, Samuels, Goodglass, & Brody, 1970).

The child learning to read stores each word in his visual long-term stores, together with the auditory and articulatory programs concerned with saying the word. The result of storing visual words is that sequential probabilities for letters are built up. Each letter in the input will tend to activate other letters that are most often found in relation to it. Lott and Smith (1970) found that even Grade 1 children showed a lower recognition threshold for three-letter words than for individual letters. By Grade 4, the children had reached adult skill in using sequential probabilities for word recognition. Mewhort (1966, 1967) presented pseudo words tachistoscopically and found that there was better identification of the letters when the approximation to English was higher (Miller, Bruner, & Postman, 1954). Separating the letters more widely destroyed this advantage, showing that it was the whole word pattern that was stored. Separating letters destroyed a basic part of this visual pattern. Mewhort (1967) also found that when two sets of letters were given simultaneously, followed by a post-exposure instruction to recall one set, the approximation to English of both words affected the recall of either. Clearly the matching process that is assumed to occur in the very first stage of processing takes longer when the material is less familiar.

A similar experiment was reported by Krueger (1970). He found that subjects could recognize a letter embedded in a set of letters faster if the set was a word than if it was not. The advantage of the word disappeared when the letters were arrayed vertically, again indicating that the visual pattern of the whole word is used to make the match. One can imagine that the stored word is run rapidly across the target letter in the visual store, while the scrambled letters must be compared one at a time with the target.

The eye-voice span and the speed of reading depend on the familiarity of the material. Redundancy plays an important part in familiarity. Redundancy in this sense means the probability that one item will follow another. There is redundancy at all levels in reading. Letters, phonemic groups, words, phrases, and sentences all have linking probabilities. Morton (1964) constructed texts with successive levels of approximation to English, and found that the speed of reading the words aloud increased with the level of

approximation up to the fifth order for slow readers and to the sixth order for fast readers. The length of the eye-voice span in words increased up to the eighth order, with the fast readers having a longer span. The efficient reader can make more use of context than the less efficient one. Unfortunately, the less skilled reader falls further and further behind, because he reads less, often very much less, and so never builds up the highly over-learned associations that predict probabilities.

Morton found that, although the speed of reading aloud was reduced by lower levels of redundancy, the eye-voice span in words was also reduced, indicating that the problem was not solely due to difficulties in verbalizing. Geyer (1968, 1970) also found that the eye-voice span in words was reduced with more difficult material, together with the speed of reading. However, he found that the temporal eye-voice span remained constant at about one second. He pointed out that this duration probably represents the optimum read-out period from the iconic image. J. Mackworth (1963b) showed that all the material in a visual input of brief duration was available for about a second with rather rapid fading thereafter.

N. Mackworth and Metzler have studied the recognition of pictures after 1-5 weeks in relation to the "informative" content of the picture, as judged by the subjects. They have found that the more informative a picture is judged to be, the better it is recognized as having been seen before. The authors also asked the subjects to decide whether any of the recognized pictures had been reversed, so that the picture to be recognized was a mirror-image of the original one. Again it was found that the reversal of the more informative pictures was more frequently recognized than that of the less informative ones. Thus, there was clearly a visual memory of the pictures against which they could be matched.

It can be concluded that there is good evidence for the suggestion of Geyer (1970) that the brief (250 msecs.) visual input during reading is transferred to a more stable iconic store, which is still visual. This stabilization of the image is probably achieved by a matching process between memorized visual patterns of words and letters and the input. At the same time that this visual material is being coded into verbal forms by motor speech programs, it is also being processed visually into more and more stable forms of memory.

VERBAL PROCESSING

Coding into Verbal Form

The speed at which a word can be coded from visual to articulatory verbal form depends on the strength of the association between these two cross-modal records. J. Mackworth

has proposed that the limited capacity for directed attention has to be divided between coding a word from visual or auditory form into verbal form, and the retention of the word in short-term memory. The comprehension of the words may also be limited by this capacity for attention.

J. Mackworth (1963a, 1963b, 1964, 1966) studied the recall of different kinds of materials (colors, digits, letters, and so on) presented in random series and found that the materials could be ordered according to the speed at which they were named aloud in a free reading situation. The same rank order was found among the materials in:

1. the number of items reported from brief visual presentations;
2. the number recalled from visual presentation at various speeds, from sixteen to one item per second;
3. the number recalled from auditory presentations at the same speeds;
4. the amount of forgetting (interference) produced by reading a set of items between presentation and recall of other material. In this case, the material that was most difficult to learn (e.g., shapes), produced most interference, but the material (e.g., digits) that was most easy to learn was also most affected by interference.

It was argued that the speed at which an item could be named was a measure of the familiarity of the relation between the item (visual or auditory name) and its verbal representation in memory. When more attention was required to name the item, less attention was available to maintain the processing and rehearsal of the material in memory. Although we see far more letters than digits, yet we very rarely name the letters. Samuels (1970) has pointed out that letter-name training does not facilitate reading acquisition. The fact that the same relationship was found with auditory material strengthens the suggestion that the auditory material also has to be coded into short-term memory by the speech motor program. Secondly, it was suggested that inter-item probability played an important part in memory and coding. We meet random sets of digits very much more often than we meet random sets of letters, and naming sequences of colors is a very unusual activity. So it can be seen how these factors of frequency of naming and familiarity of inter-item relationship act all the way through the visual-verbal processing sequence, the long-term memory stores being called into play at each stage and interacting with the efficiency of each process. The close relation between coding and memory has been discussed by Pribram (1969a) in terms of a model of brain processes. He suggests that loss of memory due to brain damage may be due more to an interference with coding than to a destruction of localized engrams.

Models of Verbal Processing

We do not know what are the basic units of the reading process. Wilson (1966) has postulated an information chunking or coding mechanism existing between the sensory buffer and the immediate working- or short-term memory. In this suggestion he follows Miller (1956). Wilson suggested that there is a hierarchy of coding routines for the processing of verbal data, proceeding from the elementary binary bit (feature recognition of letters) through graphemes, phonemes, words, phrases, and sentences. He assumed that each of these levels of synthesis produced longer "chunks," and that according to Miller's hypothesis, the number of chunks recalled would remain constant independent of the content of the chunk. However, his experiment did not altogether support this hypothesis. Three-word phrases were recalled better than three unconnected words, but not as well as single words. Moreover, some words were recalled better than others.

Wilson's finding agrees with the suggestion by J. Mackworth (1963a, 1963b) that the memory span for different kinds of materials depends on the nature of the item. Broadbent (1970) reported that Dale had found that more familiar names of counties were more likely to be recalled than less familiar ones. Yet many authors still regard each item as equivalent to any other item in experiments on short-term memory (Neisser, 1967; Norman, 1970; Waugh, 1970). This assumption ignores the fact that memory for series of items depends on a number of factors, such as the probability that one item will follow another, the familiarity of the coding link between the presented material and the name, and so on. A set of items only becomes a "chunk" as a result of a long process of learning to associate the set with its name. In considering the process of reading, particularly with regard to learning to read, we must consider the formation of chunks rather than regarding them as ready-made. The development of hierarchical probabilities of relationships between words and even phrases is an essential part of reading.

The result of developing these expectancies is that so long as the written material corresponds to the expectation, the reader can simply sample the text, leaping from one word to another farther along the text to confirm his guess (Hochberg, 1970a). As skill in reading develops, the use of peripheral vision increases. The match between input and stored data is facilitated because the anticipated word pattern is already activated by the previous intake. It is only when there is a mismatch that the reader checks and regresses to verify the mismatch. So long as the reader is attending to meaning and context rather than to individual words, his fixations can be widely spaced. Hochberg (1970b) has suggested that the ability to sample text strategically depends on peripheral search guidance arising from the peripheral intake

and cognitive search guidance arising from informed guesses as to where the important words can be found. This can be compared with the finding that children can observe an important area in a display and turn their gaze onto this area with a single eye movement (Mackworth & Otto, 1970). We use our peripheral vision, just as we use all other senses, much more for discarding unwanted material than for selecting wanted data.

Hansen and Rodgers (1965) and Rodgers (1967) have also discussed the nature of the unit in reading, and concluded that it is the Vocalic Center Group (VCG) for initial reading. The VCG is the optimally minimal sequence within which all necessary rules of phonemic co-occurrence can be stated. It is an elementary structure resulting from the integration of phonemic elements into a minimal pronunciation unit. The VCG resembles the syllable but is defined over a set of phonotactic rules. If there is only one vowel not followed by a vowel, then the VCG is a word and is decoded by reference to long-term memory. If there is more than one vowel not followed by a vowel, then special rules must be applied to the medial consonants before decoding each VCG sequentially. Once again this all-important decoding stage may be the speech motor program.

Morton (1969) has put forward a model for word recognition. This model has as its central feature a set of "logogens" which accept information relevant to a particular word response irrespective of the source of this information. When more than a threshold amount of information has accumulated in any logogen, that particular response becomes available. Information coming into the logogen decays very rapidly, disappearing in less than a second. Available responses go to the output buffer, where they are either spoken, recirculated as rehearsal, or passed into the Context System for Meaning. It may be assumed that these logogens correspond with the iconic store of Geyer, which is created by matching the visual input from the long-term memory store. We may perhaps see a "logogen" as a complex matrix involving the visual pattern of the word, its speech motor programs, and the acoustic input and output connected with it. At the same time, this matrix will include the meaning of the word (as stored sense data), its probable associated words, and various associations that have built up over the years. Such a matrix can be approached from any of these directions, and the appropriate responses and comprehension will be activated.

Wickelgren (1969) has proposed a model for speech behavior based on the "context-sensitive association theory." This model assumes that serial order in phonemes is encoded by means of associations between context-sensitive elementary motor responses. He suggests that each articulatory element of a word is stored in long-term memory as an "allophone." An

allophone is a phoneme specified by the phonemes before and after it. Thus in the word "pop" the initial p is stored as the allophone (space)-p-(o), while the final p is stored as (o)-p-(space). He concludes that a million internal representations would be sufficient for all possible allophones. Wickelgren's model has been criticized by Halwes and Jenkins (1971) on the basis that it is purely mechanical, and ignores the hierarchical use of rules for comprehending and generating words. Only by involving hierarchical structures can we hope to understand the tremendous flexibility of the brain. Halwes and Jenkins (1971) suggest that "responses are not looked up in a vast rote memory and emitted serially, but, rather, are generated by a complex processor operating on abstract entities and emitted by a very complex series of transformations." A. N. Sokolov (1969) has pointed out that language has just this function of abstraction of properties and relationships, and the generalization of concepts. "All human thought is based on language, but the relationship between thought and language is highly flexible. Internal speech is latent articulation," and the feedback between verbal kinesthesis and cognitive operations is a vital link in thought.

General Models of Memory

Most writers today believe that there are at least three different levels of memory: sensory; intermediate (short-term, secondary, or working memory); and long-term (Broadbent, 1958; Norman, 1970; Shiffrin & Atkinson, 1969; Waugh, 1970). Most writers assume that the stimulus is stored very briefly in sensory form before being coded into verbal form. The short-term store is often thought of as purely verbal (Neisser, 1967) although, in fact, sensory data must also be stored in the long-term memory and, therefore, presumably pass through the short-term store (Posner, 1969). The process of coding does not necessarily involve words. It may also involve some form of hierarchical generalization that remains in a sensory code of some kind. Little work has been done on this aspect. We may assume that comparison with long-term stored memory occurs at each stage of the processing of an input.

Although a tremendous amount of work has been done on long-term memory, it is really quite remarkable how little we know about it. Some assume that data stored in LTM is permanent--once in, it stays there forever, unchanged. Shiffrin and Atkinson (1969) have suggested that difficulties of retrieval arise not from the absence of the required data, but from the fact that search through the store becomes increasingly inefficient as new information is placed in the store. It is difficult to fit this theory of the unchanging nature of long-term memory with the finding by Bartlett (1932) that a story was steadily changed in memory until its

unfamiliar items became more readily acceptable. A constant feedback and interchange between the contents of long-term memory and the sensory input would seem a more reasonable proposition.

The brain processes material in parallel as well as serially. Pribram's (1971) hologram model describes one way in which neural activity could give rise to such parallel processing. Hunt (1971) has produced an elaborate model which compares the brain with a computer that has a system architecture activated by a program. There is a slow, subtle central computer which is surrounded by a number of high-capacity parallel-input transmission lines coming from the sense organs. These lines are controlled by a device which screens important information and provides an orderly queue of data for the attention of the central computer. This central computer contains a short-term memory for information received in the last few seconds and an intermediate-term memory which holds an abstract interpretation of events observed in the past few minutes. Both the central system and the peripheral channels have access to the very large, long-term memory (feedback), but only the central device can write into long-term memory. The input channels contain two sets of buffers: the sensory buffers, which take in data from the environment, and the intermediate buffers, which are the same for all channels. These recode the data in a way controlled by programs and data stored in long-term memory. The coding during reading involves the hierarchical recognition of features, letters, graphemes, and words. At each stage in the interrogation of LTM, a match is made between the stored pattern and the current contents of the intermediate buffer register. (See Figure 1.)

Single-State Memory Theories

Melton (1963) suggested that there was no need to postulate two different memories for short-term and long-term stores. Bernbach (1969, 1970) has also presented a model with this parsimonious assumption. He suggests that each time an item is presented or rehearsed, a replica is stored in memory. Successive replicas need not be identical. So long as there is one replica left, the item is retrievable. Replicas are destroyed on a one-to-one basis by new incoming items.

Abnormal States of Memory

On the whole it can be concluded that the bulk of the evidence favors a separate long-term memory, possibly on a molecular basis rather than a cellular basis. Ellis (1963) presented evidence which suggested that retardates may have poor short-term memories but normal long-term memories.

However, Belmont (1966) has pointed out that the data in experiments with retardates do not always distinguish between input, storage, and retrieval. Belmont considers that long-term storage may be adequate in retardates but that their difficulty may lie in coding the material into store. Since coding depends on familiarity with the code, slowness in learning has a highly cumulative effect. Belmont and Butterfield (1969) have concluded that forgetting rate decreases neither with age nor with intelligence. The differences are due to differences in acquisition or retrieval. Older and more intelligent subjects employ more active acquisition strategies. Older subjects may show better retrieval strategies than normal young children. The importance of these results for teaching and research can hardly be overestimated. Memory is a highly complex, active process, involving attention, motivation, the background of the subject's learning history, and his genetic makeup. Only by disentangling these factors can we hope to understand the workings of the brain and the potentialities and difficulties of the learner.

Spitz (1963) has pointed out that the interrelationships of functions in the central nervous system are of vital importance. Reading is a process which uses almost all of these functions. He suggested that level of intelligence is determined by the speed at which changes occur in the neural processes. Retardates may take longer to record a stimulus and longer to react to it or to code it. Once a record has been made, they will take longer than normals to change that record or stored trace when new information comes in which is relevant. It is clear that these different processes may be affected differentially by such reduced speed of neural change. Blank (1968) showed that poor readers tended to perseverate on the first word of a pair of spoken words that they were asked to imitate. Scott and Scott (1968) have also pointed out that the difficulty that retardates show in the memory-span test may be due to the fact that the information does not enter the short-term memory. In accordance with the theory of Spitz, they postulate that the long-term memory of retardates may be better than that of normal children. If this is true, then all that is needed in teaching these children is patient repetition, provided that their motivation and reinforcement are adequate (Zigler, 1966).

GENERAL CONCLUSIONS

The purpose of reading is to gain information and pleasure. As such, reading involves almost all the brain functions, sensory, motor, motivation, attention, expectancy, cognitive, and all kinds of memory. The process of reading involves coding visual symbols into a verbal code that has already been learned. Meaning is inherent in the verbal code.

The development of meaning begins even before birth and continues throughout life. Initially, it involves the synthesis of inputs from the senses, so that any particular stimulus activates a mental model that includes all other sensations that have become associated with that stimulus. These mental models include details of the temporal progression of events, so that one stimulus arouses a prediction or expectancy as to what will come next. Prediction plays a very important part in reading.

Next, the child learns a verbal spoken code for his models. This verbal code or language is stored as motor speech programs, together with the sound of the words and all the other sensory data that he has collected.

Finally he learns to read. Without adequate development of the other steps he is likely to have difficulty with this one. Language development is essential for reading. Now he learns to associate certain visual symbols with sounds, according to a complex set of rules. He now has a threefold synthesis of sensory data, verbal code, and visual symbols. When a word is read, all the elements of these complex models are activated, including the probability that certain words will come next.

It is suggested that the coding process occurs in two stages. First, the written word is matched to a word stored in visual form. The stored word is generalized, lacking specific details). This matching process is more efficient when the stored word has been activated by the previous input. All levels of storage are found, from the individual letters through spelling patterns, to words and common phrases.

It is possible to demonstrate all stages of visual memory from the brief quarter-second sensory trace to long-term storage. Experiments have suggested that the initial input and the matching process do not require attention (Doost & Turvey, 1971). Even the coding process is thought to be automatic in the skilled reader (Calfee & Jameson, 1971). However, retention of material in short-term memory, in either visual form or coded form, does require attention. Short-term memory has also been called working memory, because it apparently resembles a central computer where material is manipulated and compared with hierarchical meanings, being either discarded or recoded into meaning at a highly abstracted level. This reorganized material is now stored in long-term memory (Pribram, 1969b).

Long-term memory is a vast store of unknown nature. Some authors consider that material once entered into long-term memory remains there for life, unchanged, but others believe that there is a constant reorganization and change going on, as each new piece of information is fed into the

central computer. It would seem more in accord with the observed facts that such constant slow shifting may be occurring, since every molecule in the body changes over a few days (except, perhaps, in bone and teeth).

There is a constant interchange and feedback at all stages between long-term memory and the input. The stimulus that reaches the conscious level of attention is often so altered from the original stimulus that a completely wrong word may be "read." Sometimes the feedback will bring this discrepancy to the attention of the reader, but at other times it may go unnoticed. Learning to read involves the slow formation of a large store of data in long-term memory; in learning to read, attention must be paid to all stages of intake. Thus, in learning to read, there is very little attention available for the comprehension of what is read.

The three aspects of each kind of memory must be considered separately if an understanding of memory is desired. These three aspects are coding into memory, storage and reorganization in memory, and retrieval from memory. With children, the most important aspect is coding into memory, but with older people the difficulty lies in retrieval, because the filing system is now so vast that the categories of retrieval contain too many items for easy selection of the correct one. Organization of categories by the use of rhymes and other devices for forming strong associations is an essential part of teaching.

Attention is essential for the processing of what is read. In learning to read, or with unfamiliar material, attention is required for even the first coding level of transforming the printed word into the verbal matrix (articulation, sound, and meaning). With familiar material, much less attention is needed for this initial coding, leaving adequate attention for higher-level manipulation of words into hierarchical meaning and storing them into memory in such recoded form. Attention may be lacking for motivational reasons, for physiological reasons (e.g., hunger) or because of immaturity. Even when there is enough available capacity of attention, there may be poor performance because of difficulty in the early stages of coding.

The purpose of reading can, therefore, be defined in the broadest possible terms as the achievement of a three-way synthesis among meaning (originally formed from sense data), the spoken word, and the written word.

REFERENCES

Aderman, D., & Smith, E. E. Expectancy as a determinant of functional units in perceptual recognition. Cognitive Psychology, 1971, 2, 117-129.

Allen, D. Another look at formal similarity. Paper presented at the meeting of the American Psychological Association, Miami Beach, Florida, September 1970.

Athey, I. Affective processes in reading. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 98-119.

Bartlett, F. C. Remembering. England: Cambridge University Press, 1932.

Bay, E. Aphasia and conceptional thinking. In L. Halpern (Ed.), Problems of dynamic neurology. Jerusalem: Hebrew University, 1963. Pp. 1-12.

Belmont, J. M. Long-term memory in mental retardation. International Review of Research in Mental Retardation, 1966, 1, 219-255.

Belmont, J. M., & Butterfield, E. C. The relations of short-term memory to development and intelligence. In L. P. Lipsitt & H. W. Reese (Eds.), Advances in child development and behavior. Vol. 4. New York: Academic Press, 1969.

Bernbach, H. A. Replication processes in human memory and learning. In G. H. Bower & J. T. Spence (Eds.), The psychology of learning and motivation. Vol. 3. New York: Academic Press, 1969. Pp. 201-240.

Bernbach, H. A. A multiple copy model for post-perceptual memory. In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970. Pp. 103-116.

Blank, M. Cognitive processes in auditory discrimination in normal and retarded readers. Child Development, 1968, 39, 1091-1101.

Briggs, J. B. Coding and cognitive behaviour. British Journal of Psychology, 1969, 60, 287-305.

Broadbent, D. B. Perception and communication. London: Pergamon Press, 1958.

Broadbent, D. B. Unpublished paper, 1970.

Butters, N., Barton, M., & Brody, B. A. Role of the right parietal lobe in the mediation of cross-modal associations and reversible operations in space. Cortex, 1970, 6, 174-190.

Butters, N., & Brody, B. A. The role of the left parietal lobe in mediation of intra- and cross-modal associations. Cortex, 1968, 4, 328-343.

Butters, N., Samuels, I., Goodglass, N., & Brody, B. A. Short-term visual memory in brain-damaged patients. Paper presented at the meeting of the American Psychological Association, Miami Beach, Florida, September 1970.

Calfee, R. C., & Jameson, P. Visual search and reading. Journal of Educational Psychology, 1971, in press.

Cattell, J. McK. The time it takes to see and name objects. Mind, 1886, 11, 63-65.

Cohen, G. A comparison of semantic, acoustic, and visual criteria for matching of word pairs. Perception and Psychophysics, 1968, 4, 203-204.

Cohen, G. Some evidence for parallel comparisons in a letter-recognition task. Quarterly Journal of Experimental Psychology, 1969, 21, 272-279.

Crosby, R. M. N., & Liston, R. A. Reading and the dyslexic child. London: Souvenir Press, 1968.

Doost, R., & Turvey, M. T. Iconic memory and central processing capacity. Perception and Psychophysics, 1971, 9, 269-274.

Ellis, N. R. The stimulus trace and behavioral inadequacy. In N. R. Ellis (Ed.), Handbook of mental deficiency. New York: McGraw-Hill, 1963. Pp. 134-158.

Fitts, P. M. Perceptual-motor skill learning. In A. W. Melton (Ed.), Categories of human learning. New York: Academic Press, 1964. Pp. 244-285.

Fristoe, M., & Blanton, R. L. Like- and cross-modality recognition at two levels of meaningfulness in a short-term memory task. Paper presented at the meeting of the American Psychological Association, Miami Beach, Florida, September 1970.

Geyer, J. J. Perceptual systems in reading: The prediction of a temporal eye-voice span constant. In H. K. Smith (Ed.), Perception and reading. Newark, Del.: International Reading Association, 1968. Pp. 44-53.

Geyer, J. J. Models of perceptual processes in reading. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 47-94.

Gibson, E. J., Pick, A., Osser, H., & Hammond, M. The role of grapheme-phoneme correspondence in the perception of words. American Journal of Psychology, 1962, 75, 554-570.

Goodman, K. S. Reading: A psycholinguistic guessing game. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 259-272.

Hansen, D., & Rodgers, T. S. An exploration of psycholinguistic units in initial reading. Report No. 74, 1965, Institute for Mathematical Studies in the Social Sciences, Stanford University.

Halwes, T., & Jenkins, J. J. Problem of serial order in behavior is not resolved by context-sensitive associative memory models. Psychological Review, 1971, 78, 122-129.

Hochberg, J. Attention in perception and reading. In F. A. Young & D. B. Lindsley (Eds.), Early experience and visual information processing in perceptual and reading disorders. Washington, D.C.: National Academy of Sciences, 1970. Pp. 219-224. (a)

Hochberg, J. Components of literacy: Speculations and exploratory research. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. Pp. 74-89. (b)

Holmes, J. A. The substrata-factor theory of reading: Some experimental evidence. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 187-197.

Hunt, E. What kind of computer is man? Cognitive Psychology, 1971, 2, 57-98.

Hyden, H. The question of a molecular basis for the memory trace. In K. H. Pribram & D. E. Broadbent (Eds.), Biology of memory. New York: Academic Press, 1970. Pp. 101-119.

Kling, M. General open-systems theory and the substrata-factor theory of reading. In A. J. Kingston (Eds.), Highlights of the preconvention institutes, 1965. Newark, Del.: International Reading Association, 1966. Pp. 79-123.

Kolers, P. A. The recognition of geometrically transformed text. Perception and Psychophysics, 1968, 3, 57-64.

Kreuger, L. E. Visual comparisons in a redundant display. Cognitive Psychology, 1970, 1, 341-357.

Lansdell, H. Effect of temporal lobe ablations on two lateralized deficits. Physiology and Behavior, 1968, 3, 271-273.

Liberman, A. M., Cooper, F. S., Shankweiler, D. P., & Studdert-Kennedy, M. Perception of the speech code. Psychological Review, 1967, 74, 431-461.

Lott, D., & Smith, F. Knowledge of intraword redundancy by beginning readers. Psychonomic Science, 1970, 19, 343-344.

Mackworth, J. F. The visual image and the memory trace. Canadian Journal of Psychology, 1962, 19, 55-59.

Mackworth, J. F. The duration of the visual image. Canadian Journal of Psychology, 1963, 17, 62-81. (a)

Mackworth, J. F. The relation between the visual image and the post-perceptual immediate memory. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 75-85. (b)

Mackworth, J. F. Auditory short-term memory. Canadian Journal of Psychology, 1964, 18, 292-303.

Mackworth, J. F. Perceptual coding as a factor in short-term memory. Canadian Journal of Psychology, 1966, 20, 18-33.

Mackworth, J. F. Vigilance and habituation: A neuropsychological approach. London: Penguin Books, 1969.

Mackworth, J. F. Vigilance and attention: A signal-detection approach. London: Penguin Books, 1970.

Mackworth, N. H., Grandstaff, N. W., & Pribram, K. H. Prolonged orientation to pictorial novelty in severely speech-disordered children. Neuropsychologia, 1971, in press.

Mackworth, N. H., & Morandi, A. J. The gaze selects informative details within pictures. Perception and Psychophysics, 1967, 2, 547-552.

Mackworth, N. H., & Otto, D. A. Habituation of the visual orienting response in young children. Perception and Psychophysics, 1970, 7, 173-178.

Melton, A. W. Implications of short-term memory for a general theory of memory. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 1-21.

Mewhort, D. J. K. Sequential redundancy and letter spacing as determinants in tachistoscopic recognition experiment. Canadian Journal of Psychology, 1966, 20, 435-444.

Newhort, D. J. K. Familiarity of letter sequences, response uncertainty, and the tachistoscopic recognition experiment. Canadian Journal of Psychology, 1967, 21, 309-321.

Miller, G. A. The magical number seven, plus or minus two: Some limits on our capacity of processing information. Psychological Review, 1956, 63, 81-97.

Miller, G. A., Bruner, J. S., & Postman, L. Familiarity of letter sequences and tachistoscopic identification. Journal of General Psychology, 1954, 50, 129-139.

Miller, G. A., Galanter, E., & Pribram, K. H. Plans and the structure of behavior. New York: Wiley, 1960.

Morton, J. The effects of context upon speed of reading, eye movements, and eye-voice span. Quarterly Journal of Experimental Psychology, 1964, 16, 340-354.

Morton, J. Interaction of information in word recognition. Psychological Review, 1969, 76, 165-178.

Murdock, B. B. Auditory and visual stores in short-term memory. Acta Psychologia, 1967, 27, 316-324.

Murdock, B. B. Modality effects in short-term memory: Storage or retrieval. Journal of Experimental Psychology, 1968, 77, 79-86.

Neisser, U. Cognitive psychology. New York: Appleton-Century-Crofts, 1967.

Neisser, U., & Beller, H. K. Searching through word lists. British Journal of Psychology, 1965, 56, 349-358.

Norman, D. H. (Ed.) Models of human memory. New York: Academic Press, 1970.

Paivio, A. Mental imagery in associative learning and memory. Psychological Review, 1969, 76, 241-263.

Posner, M. I. Abstraction and the process of recognition. In G. H. Bowers & J. T. Spence (Eds.), The psychology of learning and motivation. Vol. 3. New York: Academic Press, 1969. Pp. 44-100.

Posner, M. I., & Keele, S. W. Decay of visual information from a single letter. Science, 1967, 158, 137-139.

Posner, M. I., Boies, S. J., Eichelman, W. H., & Taylor, R. L. Retention of visual and name codes of single letters. Journal of Experimental Psychology, 1969, 79, 1-16.

Posner, M. I., & Konick, A. F. Short-term retention of visual and kinesthetic information. Organizational Behavior and Human Performance, 1966, 1, 71-86.

Pribram, K. H. The amnestic syndromes: Disturbances in coding? In G. A. Talland & N. C. Waugh (Eds.), Pathology of memory. New York: Academic Press, 1969. Pp. 127-157. (a)

Pribram, K. H. The four R's of remembering. In K. H. Pribram (Ed.), On the biology of learning. New York: Harcourt, Brace & World, 1969. Pp. 191-225. (b)

Pribram, K. H. Looking to see: Some experiments on the brain mechanisms of attention in perception. In D. A. Hamburg, K. H. Pribram, & A. J. Stunkard (Eds.), Perception and its disorders. Baltimore: Williams & Wilkins, 1970. Pp. 150-162.

Pribram, K. H. The language of the brain. Englewood Cliffs, N. J.: Prentice-Hall, 1971.

Reed, D. W. A theory of language, speech, and writing. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 219-238.

Rodgers, T. Linguistic considerations in the design of the Stanford computer-based curriculum in initial reading. Report No. 111, 1967, Institute for Mathematical Studies in the Social Sciences, Stanford University.

Rosenfeld, J. B. Coding processes in short-term memory. Paper presented at the meeting of the American Psychological Association, Miami Beach, Florida, September, 1970.

Sales, B. D., Haber, R. N., & Cole, R. A. Mechanisms of aural encoding. IV: Hear-see, say-write, interactions for vowels. Perception and Psychophysics, 1969, 6, 385.

Samuels, S. J. Modes of word recognition. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 23-37.

Scott, K. G., & Scott, M. S. Research and theory in short-term memory. International Review of Research in Mental Retardation, 1968, 3, 135-162.

Shiffrin, R. M., & Atkinson, R. C. Storage and retrieval processes in long-term memory. Psychological Review, 1969, 76, 179-193.

Singer, H., & Ruddell, R. B. (Eds.) Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970.

Sokolov, A. N. Studies of the speech mechanism in thinking. In M. Cole & I. Maltzman (Eds.), A handbook of contemporary Soviet psychology. New York: Basic Books, 1969. Pp. 531-573.

Sokolov, E. N. Modeling properties of the nervous system. In M. Cole & I. Maltzman (Eds.), A handbook of contemporary Soviet psychology. New York: Basic Books, 1969. Pp. 671-704.

Sperling, G. The information available in brief visual presentations. Psychological Monographs, 1960, 74.

Sperling, G. Successive approximations to a model for short-term memory. In A. F. Sanders (Ed.), Attention and performance. Acta Psychologica, 27, 1967. Pp. 285-292.

Sperling, G. Short-term memory, long-term memory, and scanning in the processing of visual information. In F. A. Young & D. B. Lindsley (Eds.), Early experience and visual information processing in perceptual and reading disorders. Washington, D.C.: National Academy of Sciences, 1970. Pp. 198-215.

Sperry, R. W., & Gazzaniga, M. S. Language following surgical disconnection of the hemispheres. In C. H. Millikan & F. L. Darley (Eds.), Brain mechanisms underlying speech and language. New York: Grune & Stratton, 1967. Pp. 108-114.

Spinelli, D. N. OCCAM: A computer model for a content-addressable memory in the central nervous system. In K. H. Pribram & D. E. Broadbent (Eds.), Biology of memory. New York: Academic Press, 1970. Pp. 193-306.

Spitz, H. H. Field theory in mental deficiency. In N. R. Ellis (Ed.), Handbook of mental deficiency. New York: McGraw-Hill, 1963. Pp. 11-40.

Standing, L., Haber, R. N., Cataldo, M., & Sales, B. D. Two types of short-term visual storage. Perception and Psychophysics, 1969, 5, 193-194.

Sternberg, S. Two operations in character recognition: Some evidence from reaction-time measurements. Perception and Psychophysics, 1967, 2, 45-53.

Taylor, R. L., & Reilly, S. Naming and other methods of decoding visual information. Journal of Experimental Psychology, 1970, 83, 80-83.

Turvey, M. T., & Egan, J. F. Release from proactive interference in short-term memory as a function of change in visual and phonemic structure and retention interval. Perception and Psychophysics, 1970, 7, 169-172.

Walter, W. G. Can attention be defined in physiological terms? In C. R. Evans & T. B. Mulholland (Eds.), Attention in neurophysiology. London: Butterworths, 1969. Pp. 27-39.

Waugh, N. C. Primary and secondary memory in short-term retention. In K. H. Pribram & D. E. Broadbent (Eds.), Biology of memory. New York: Academic Press, 1970. Pp. 63-66.

Wheeler, D. D. Processes in word recognition. Cognitive Psychology, 1970, 1, 59-85.

Wickelgren, W. A. Context-sensitive coding, associative memory, and serial order in (speech) behavior. Psychological Review, 1969, 76, 1-15.

Wilson, H. A. An investigation of linguistic unit size in memory processes. Report No. 102, Institute for Mathematical Studies in the Social Sciences, Stanford University, 1966.

Zigler, E. Research on personality structure in the retardate. International Review of Research in Mental Retardation, 1966, 1, 77-108.

SEVEN COGNITIVE SKILLS IN READING

Norman H. Mackworth

Stanford University

LESSONS FROM THE LITERATURE SEARCH

1. Synthesis Is Possible

One of the next steps is to spotlight about five hundred high-quality papers or books to bring them out of the shadows thrown by the awesome 8,544 references that have already been listed. This could be done if each reviewer-evaluator would list his favorite hundred references, as I have done in the bibliography ending this paper. This could perhaps lead to a consensus and a final list of five hundred contributions. I believe that many would find this of greater value than the complete listing, useful as that will be.

2. New Ideas for Experimental Research

The sixties have seen the rise of neuropsychology, experimental child psychology, cognitive psychology, and psycholinguistics; these have been combined with a much better understanding of skilled human performance at continuous tasks. A great deal of this improved knowledge of how people think and act has arisen from comparisons of the similarities between the schematic models of human information processing and similar models for electronic computation. But even more has been learned from the differences between human and computer data processing.

3. The Feedback Control Principle Has Been One of the Main New Concepts That Have Arisen From Similarities Between Neuropsychology and Computer Data Processing

For instance, there is a great resemblance between man and machine in regard to this aspect of feedback control. J. Mackworth (1971) has emphasized this in her model of the reading process.* She hypothesizes that long-term memory

---

*See her paper in this report: J. F. Mackworth. Some models of the reading process: Learners and skilled readers. Figure 1.

controls perception at five different levels, beginning with the acquisition of the next visual stimulus by eye movements. Such feedback loops mean that experience often determines what we see. One result is that the gaze selects distinctive features discovered over the years as being particularly significant and therefore memorable (Kolers, 1970; Mackworth & Morandi, 1967). No adult looks without looking backwards as well as forwards. Our expectancies and predictions make it possible to read as rapidly as we do. Internal representations of external events obviate the need for completely continuous checking between the actual and the expected events. These internal programs provide grammatical probabilities as well as trends related to the acquisition of meaning from the words being read.

Paradoxically, then, it has been the studies of machines that have assisted the development of cognitive psychology. In this new subject, it is one of the basic tenets that it is now legal (and indeed essential) to consider at times how people put it all together. That is to say, how they combine their input stimuli with their in-head models. What are these models, anyway? They are internal models or cerebral representations of reality; Pribram (1970a, 1971a) has made a most useful distinction between images of events and images of achievement. Images of <u>events</u> are those, for example, that enable us to detect a novelty, classify it, and dismiss it, so as to be ready for the next new event in the environment. Images of <u>achievement</u> are evaluative models or prototypes that provide targets of excellence for thought or manual skill.

4. The Hierarchical Nature of Human Thinking Is the Second Great Parallel Between Man and Modern Computers

The ease with which humans can perceive and classify visual patterns (such as actual human faces) is, however, a problem that completely defeats machines. But computers can (and do) use a hierarchical process to classify printed letter shapes. In other words, they do not run through all of the possible comparisons between stimulus shape and template; instead, they discard whole groups of impossible matchings by applying a series of classification rules, which start with the widest possible classes and successively narrow down the basis of judgment. Gibson (1966) has shown that even seven-year-old children use a hierarchical classification tree when they are reading uppercase letters; their method is only slightly different from that of adults.

5. The Vital Role of Pictorial Processing

The great importance of the shape-recognition studies of letters partly rests on the very recent idea that human

data processing of uppercase letters may well use visuo-spatial routes which speed directly from external stimulus through iconic store into short-term memory without any necessary coding of the input into names or speech-motor programs (Cohen, 1969; J. Mackworth, 1971; Posner, Boies, Eichelman, & Taylor, 1969). Good historical reasons exist for linking picture processing with reading of printed text. Many believe that most of the individual letters of our alphabet started out as pictures. "A" was a picture of an ox and "B" was a picture of a house; incidentally many letters show marked rotation over the centuries--as if one of their least stable features was this orientation of the characters on the plane of the writing surface.

The main reason for studying pictorial processing is, however, the simple fact that children who have difficulty in reading often show faulty pictorial processing, as we shall see later. By studying pictorial processing, we are often able to learn about the information that the person brings to the picture as well as how he is processing the external stimuli in the display (Kolers, 1970a; N. Mackworth & Bruner, 1970).

6. Attention and Failures of Attention Are Human Attributes Which Are Virtually Unknown to Machines

They are, therefore, often overlooked when data processing is regarded as a matter only for machines. Many authors have suggested that reading failures may arise from lack of attention; this aspect should be studied in any comprehensive examination of a young child who is having serious difficulty in reading. The two recent books by J. Mackworth (1969, 1970) on the problems of attention in vigilance emphasize that studies of human ability to detect signals should be supplemented by electrophysiological recordings of evoked potentials and expectancy waves during the alertness tasks.

7. The Need for a Research Program on Reading Skills Has Become Very Clear

We have a considerable amount of new knowledge from both basic research and practical sources. These new data should now be examined in relation to the practical problems experienced by eight million children in the United States who need individual treatment for difficulties in reading. We know from two recent Government surveys by Chalfant and Scheffelin (1969) and by Templeton (1969) that these highly important practical problems facing so many children and their parents simply cannot be solved without more information about the cognitive processes involved in normal and abnormal reading, and without a better understanding of the nature of the difficulties.

In brief, we need to combine new ideas about (a) feedback from memory; (b) the hierarchical nature of human thinking; and (c) the significant role of pictorial processing in reading with recent electronic advances, such as television and the videotape cartridge, which provide important ways of accelerating reading training. Advances in computer knowledge in the form of computer-assisted instruction have enabled Atkinson and his colleagues at Stanford (1970) to demonstrate how much can be done for initial reading by computer control. Videotape methods have already effectively speeded up the automatic analysis of data from line-of-sight recording; and they have made it feasible for more detailed studies to be undertaken by eye-camera methods. New work would build on this improved procedure now that we can instantly record the changing stimulus scene and the X-Y coordinates of eye position on the same videotape that is recording the ongoing brainwave electrical patterns from the reader.

OUTLINE OF RESEARCH PROGRAM

The seven skills in reading that most urgently need study can be grouped under the three main headings: (a) Pictorial Processing, (b) Verbal Processing, and (c) Attention.

Pictorial Processing

Skill 1. Recognizing Left-Right Pattern Reversal

We need a simple and interesting test of the ability of children to recognize whether colored landscapes have been left-to-right reversed since they were last seen. We know that normal children only gradually develop an ability to recognize whether a visual spatial pattern has been reversed or even inverted (Huttenlocher, 1967; Rudel & Teuber, 1963). Children with reading disorders often have difficulty with visuo-spatial tests of this kind (Lovell & Gorton, 1968). Slow readers may, for instance, mistake b for d, or even p for d. Such children may reverse the numbers in their drawing of a clock face or even draw a house completely upside down (Critchley, 1970).

Quantitative studies of a new test for this recognition of left-right pattern reversal have now been started by Mackworth and Metzler. Attempts have been made to discover ways of making the task sensitive by increasing the difficulty of the situation. Two ways have been found. Obviously, the more symmetrical the pattern, the more difficulty the subject has in recognizing when the picture has been turned around. Less obvious is our finding that the estimated informativeness of the test picture, in the sense of estimated recognizability, also has a very considerable influence on the difficulty of

the task. Even adults are quite unable to do better than chance after one to five weeks have elapsed between the initial presentation and the test presentation when the pictures used are estimated as being difficult to recognize. Informative pictures show the traditionally highly accurate recognition scores (around 90 percent correct). We now need to shorten the elapsed time between initial and test exposures and use these tests on normal children prior to the examination of children with reading disorders. This evidence is relevant to matters such as the ability to recall verbal material. We have established that estimated informativeness is the same subjective dimension as the concreteness-abstractness dimension studied by Paivio (1969). Many workers have, in general, confirmed his discoveries that the more abstract the picture or the word the more difficult the material is to retain.

Skill 2. Transforming a Visuo-Temporal Sequence into a Visuo-Spatial Pattern

It has long been known that the comprehension of spoken speech is related to the comprehension of printed words in normal children. It is therefore likely that we can learn about possible tests for children with reading disorders by considering tasks that have shown impairment in children who are known to have difficulty in comprehending speech. A clear example of such a test is that used by Poppen, Stark, Bisenson, Forrest, and Wertheim (1969). This short-term memory test gave four times as many errors for speech-disordered children. They had 40 percent errors when, after 17 seconds, they had to recall the order in which a three-item array of lights was flashed on. Children with reading disorders may also have some difficulty in remembering a simple spatial sequence of this type.

Already it has been established that retarded readers have unusual difficulty for their age group in converting a time series into a spatial series. Blank and Bridger (1966, 1967) have noted that retarded readers make many more errors in recognizing a given sequence of four flashes of light coming from one spatial position. The lights come on for one-quarter of a second and are usually half a second apart, but there are also long pauses which last for one second each. The subject looks at the short sequence of flashes and is then given a multiple-choice answer sheet in which various alternative spacings of four lights across time are represented by a visuo-spatial code. Dyslexics had difficulty in marking the visuo-temporal sequence they had just seen. There is no doubt about the finding. But there is much controversy about the explanation for this difficulty. Bridger (1970) claims that this is a naming problem; Butters and Brody (1968) found performance on an audio-visual matching task of this kind to be

worse in adults with left-lobe brain damage. The left lobe is often the main language region. However, Belmont, Birch, and Belmont (1968) have rejected the idea that this is a naming difficulty, since adult aphasics with naming difficulties had no more errors than normal adults. Goodnow (1969) has also rejected the idea that normal kindergartners have this difficulty because of a specific language disability. She suggests, from an audio-visual form of this task, that the children have two possible sources of trouble. They find it hard to "chunk" the series to form a representation of the effect of the longer time interval dividing the items into groups. In addition, they have trouble in using a spatial gap or visual distance to represent a gap in time. Pribram (1969) interprets this phenomenon as arising from a difficulty in relating the alternative answers to the recent experience of the time sequence. Pribram calls this ability "parsing," and believes that parsing difficulties arise when organisms have trouble in placing the stimulus in its appropriate context; this is more than merely a failure to hold the material in the working memory.

Skill 3. Image Formation and the Use of Internal Representations

Eye-camera methods have led to a new procedure whereby we can test even two-year-old children (N. Mackworth, 1968). This method has in its turn led to a procedure that makes it possible to determine how quickly children can establish an internal representation of an external event. Mackworth and Otto (1970) have demonstrated that even two-year-old children can do this very quickly within a matter of a few seconds. The experiment showed that normal children first of all spent two-thirds of their time looking at a novel item, when this suddenly colored up amongst a set of 16 objects. They soon formed an internal image of this novel event and usually looked away from it by 15 seconds or less from the start of the novelty, despite the fact that the novel item stayed on view for one minute. The children with marked language difficulty and strong clinical signs of troubles in speech comprehension behaved quite differently from normals and from other children who had only mild aphasia. Mackworth, Grandstaff, and Pribram (1971) have shown that these children with severe speech-comprehension difficulty stared and stared at the novel item for at least one minute and showed no signs of forming any internal representation that would have allowed them to look away from it.

A full-scale study of this phenomenon among both dyslexic and normal children is needed. The prediction is that slow readers might be slow in forming an image of this novel event. Once again, they might stare at the novel color longer than normals. The reason why this is a handicap clearly rests

on the idea that normally the gaze should register an external novelty quickly. In any fast-changing situation, each event should be rapidly discarded to free the organism to look out for the next novelty somewhere else. Spring (1970) has noted how children who are two years behind in their reading achievement are slow at matching two uppercase letters. Further work by Grandstaff, Mackworth, and de la Pena has demonstrated that children with speech disorders of comprehension are twice as slow as normals to leave the correct pattern in a visual match-to-sample task.

The use of internal representations once formed is also of great interest as a possible research tool. Bay (1962, 1963) has already established that serious language disabilities are accompanied by much more fundamental troubles than were failures in word manipulation. Such patients do not comprehend words because they do not classify their prototype concepts of objects sufficiently clearly. He makes the point that verbal mislabeling will occur when anyone is unfortunate enough to confuse the category of "Bird" with that of "Fish." This was rather like the famous Escher drawings showing one pattern merging into another. The basic problem in these aphasic patients is conceptual in regard to the internal images being used to represent external events. This trouble has been graphically illustrated by photographs of actual three-dimensional models produced in modeling clay; for example, when an adult patient was trying to make a crocodile he produced an oversimplified snakelike creature without any feet or any head.

Such ideas about failure to use internal representations are very hard to examine experimentally, but Shepard and Metzler (1971) have recently done some experiments at Stanford that provide a straightforward way of testing this ability. They asked people to decide whether two pictures placed side by side were the same or different. The pictures were two flat images of three-dimensional objects. The only way the subjects could decide whether one object could be fitted to the other was to rotate one of the patterns mentally. These investigators have shown that there is a linear relationship between the number of degrees through which such patterns have to be rotated and the time needed to discover the answer to the problem. Such tests could readily give quantitative readings for slow readers and for normal readers. In addition, eye-camera studies could analyze whether very skilled viewers make fewer point-to-point matching movements between individual features.

Verbal Processing

Skill 4. Matching Sentences to Pictures

When Zigler, Jones, and Kafes (1964) analyzed the acquisition of language habits in first-, second-, and

third-grade normal boys, they found that the Language Modalities Test for Aphasia indicated that language processes could usefully be subdivided into various skills. Some of these skills showed considerable differences between the three different school grades examined; others did not. An important side-finding was that the presence of anxiety did not affect the results because the research situation was presented as a game rather than as an evaluative test. In order of merit, the tests of verbal comprehension that were most effective in separating the third-graders from the first-graders were as follows:

1. Matching of printed words to pictures;
2. Matching of printed sentences to pictures;
3. Matching of spoken sentences to pictures.

This pioneer work needs extension, especially as the data were so clear-cut. As regards the matching of single printed words and pictures, subsequent work has shown that studies in this area have a bearing on recognition. For example, Chan and Travers (1966) and many others have demonstrated that the recognition of visual patterns consisting of silhouette-like figures is more accurate when these figures are displayed along with meaningful relevant names. Perceptual learning was assisted by combining the printed and pictorial stimuli. This finding may be related to the idea that a picture does not always represent the same concept as a word. For instance, Deno, Johnson, and Jenkins (1968) found that the free associations elicited by a given word and those elicited by an easily recognized line drawing (intended to represent the same concept) may differ very considerably. Indeed the overlap between the associations elicited by two such stimuli is quite often less than that between two words representing different concepts.

Zigler, Jones, and Kafes (1964) emphasized that the matching of printed or spoken sentences to pictures is a task that makes the children attend to all the syntactic or semantic features of the stimulus situation. Studies could be made of the extent to which children with reading disabilities make mistakes in matching printed sentences and pictures. Suppose there was a series of single 8 x 10 inch pictures and below each picture there was a sentence placed like a caption. The child would have to say whether the caption was appropriate for the picture. An eye-camera analysis of where the child looked could help to indicate the nature of the reasons why errors were made. Perhaps the pictorial scanning might be quite inadequate, as Vurpillot (1968) showed in her eye-camera analysis of why four-year-olds failed when they were asked to match picture pairs for absolute similarity. Alternatively, the children may fail to find the important areas within pictures, as in the Mackworth and Bruner (1970) study. Clearly too, the way in which the child segmented the words in a

sentence with his eye movements would be important, in view of the evidence from Mehler, Bever, and Carey (1967). The child could sometimes be helped by arranging the sentence into its linguistic segments by special typographic arrangement. Alternatively, the sentences accompanying the pictures could sometimes be presented sequentially by tape recorder to discover whether the child was scanning across the pictures in a sequence based on the prompting of the spoken sentence.

Another way to discover how sentences are matched with pictures would be to display in the eye camera eight pictures encircling a printed sentence. The task could be quite easy or quite difficult, depending on how abstract was the sentence with each set of pictures. (To avoid too many chance successes, the children would be asked to point at the two pictures from the set that represented the idea conveyed by the sentence.)

Skill 5. Word Prediction from a Grammatical Framework

Kolers (1970b) has made the point that college students made many errors when they were reading aloud from optically transformed text. The chief error was the substitution of an English word not shown. He analyzed the nature of the errors and found that the substitution was often of the same part of speech as the original word. This was especially true for nouns, verbs, and prepositions. In brief, the adults were sensitive to the grammatical frameworks of the sentences even when they misread words.

This work needs extension by studying word prediction during eye-camera recording. One way to accomplish this would be to supply printed or spoken sentences, in each of which there was a nonsense word. The subject would know that somewhere on the rest of the page below the sentence the missing word would be found. The display page would be divided into quadrants, each quadrant containing lists of only one part of speech; e.g., nouns, verbs, adjectives, or adverbs. Poor readers might look for the missing words among the wrong parts of speech. Another starting point in this work would be the studies of Weber described in Project Literacy (Levin, Gibson, & Gibson, 1968). Weber analyzed the extent to which first-graders used the grammatical context in reading aloud. She found that beginning readers of normal ability do in fact use their knowledge of grammar to narrow down the search for a word that should compete for a given slot in the sentence.

Effective reading depends largely on prediction. When the text does not conform to expectation, regressive eye movements occur in order to resolve the disagreement. Morton (1964) compared reading aloud ordinary text and disconnected words. He found that there were half as many consecutive eye

movements and twice as many words in the eye-voice span with the connected text. Geyer (1966) found that the duration of the eye-voice span remained constant at about one second with different texts, but the number of words in this eye-voice span varied with the difficulty of the text. It took longer to process words that were less predictable.

Nearly ten years ago, Miller (1962) suggested that sentence perception depended on coding words into larger units by grouping them in chunks, each consisting of a single phrase. Levelt (1970) has now demonstrated on 120 normal subjects that people group their words into chunks according to a hierarchical process. Here we see a parallel process at work in a syntactical procedure; this grouping implies that the word shapes are being processed visually at the same time that various principles of syntactic organization are being brought into play. Levelt studied the perception of short spoken sentences heard against a noise background. His main measure was the probability that a given word would be correctly reported. Computer analysis for clustering of the data showed two main findings: (a) that the words that were grouped together were always adjacent to each other, and (b) the hierarchical tree structure from the cluster data closely matched the grammatical structures that were predictable solely from a theoretical linguistic analysis. The observed and predicted chunks were, in fact, phrases.

This kind of linguistic analysis clearly needs to be related to experimental data such as the valuable evidence described by Wanat (1968, 1971). He has established, by eye-camera methods, that there are several clear relationships between the linguistic structure of the short sentences and the eye-fixation patterns with which they are processed when young adults are reading aloud. Several students are working at Stanford under the direction of Bower (1970) on the ways in which the hierarchical organization of sentences affects the extent to which the material is remembered.

Forster (1970) has demonstrated interesting phenomena regarding the effects of grammatical structure on the perception of sentences. For instance, six-word sentences were scrambled and then presented, one word at a time, on six successive frames of a motion-picture film running at 16 frames per second. His subjects (college students) wrote down their answers in ways that made it clear that they were often rearranging the series of words into a more grammatical sequence. When they did this, they tended to report many more words than when they did not.

Skill 6. Grasping Sentence Meaning from Verbal Context

Comprehension. The central position of comprehension in reading has led Goodman (1968) to the view that reading is

not really reading unless there is some degree of comprehension. The full complexity of the reading process is revealed by the great difficulties involved in trying to analyze the nature of comprehension.

We are fortunate in having the work of Davis (1944, 1968) to start from since his studies are among the most extensive investigations in the whole area of reading. Davis has established on as many as 988 twelfth-graders that reading comprehension is not, in fact, a unitary trait. He noted about eight different skills in his examination of the nature of reading comprehension in mature readers. The four skills having the largest amount of unique nonchance variance were found to be:

a. Recall of word meanings;
   Example: Guffaw most nearly means
   A make fun of.
   B sneeze.
   C cough.
   D laugh.
b. Recognizing a writer's purpose, attitude, tone, and mood;
   Example: The golf links lie so near the mill
   That almost every day
   The laboring children can look out
   And see the men at play.
   This verse was written about 1915 and refers to a social problem of the period --child labor. The tone of the verse is
   A resigned.
   B belligerent.
   C bitterly ironic.
   D mournful.
c. Following the structure of a passage;
   Example: See below.
d. Drawing inferences about word meaning from the context;
   Example: See below.

There is much to be said for the idea that the extension of these investigations of comprehension should be central to any experimental program for analyzing reading disorders in children. The first question after the existence of the skills has been established is whether they can be arranged in any hierarchical order. Hackett (1968) and others are working on this question and claim that there is evidence that certain skills are at the top of the hierarchical tree structure and that others are near the bottom. It seems likely that the hierarchy of skills is probably somewhat dependent on the age level of the readers. Nevertheless, the Hackett study is of real interest, especially from a methodological point of view. For example, one approach used in this study is to discover the extent to which attainment of

one skill can be predicted from attainment of another. Hackett analyzed the probability of obtaining a correct response on a test of Skill X2 when Skill X1 is known to have been completely mastered.

Davis (1968) illustrates his skill c, listed above, as follows:

Example: Only the adult male cricket chirps. On a summer night, they sing by the thousand in unison, so that the forest seems to pulsate and the tiny unseen orchestra becomes its very voice.
"Its" (in the last line) refers to
A adult male cricket.
B summer night.
C forest.
D tiny unseen orchestra.

Davis' skill d, as listed above, would lend itself to an eye-camera analysis of why the children fail to understand. One way of achieving this effect might be to adopt a procedure suggested many years ago by Werner and Kaplan (1950), using the Word-Context Test, which they gave to 8-1/2- to 13-1/2-year-old children. There were six sentences per item, each containing the same artificial word.

Example:
1. We will admire people who have much sackoy.
2. You need sackoy when you start to do a hard job.
3. If you have done something wrong and you are not afraid to tell the truth, you have sackoy.
4. A person who saves a baby from drowning has much sackoy.
5. Soldiers must have sackoy when they are on the battlefield.
6. You need sackoy to fight with a boy bigger than you.

What is sackoy?

Comprehension and early eye-movement research. Fifty years ago, Charles H. Judd worked on the effect of unfamiliar sentences on eye-movement fixation patterns. Judd and Buswell (1922) concluded that it was impossible to look with complacency on the mental and nervous disorganization that seemed to be the major outcome of two and one-third years of training on students of Latin in seven top-grade high schools.

Judd and Buswell (1922) questioned the merit of always asking for either a grammatical analysis or a verbatim reproduction of Latin or French texts because the eye-movement patterns accompanying such tasks were completely different from those obtained when the students were reading for an understanding of the printed passage.

Parallel processing in reading. We have already noted that students who are reading their own language make predictions about the grammatical structures while they are grasping the meaning of the prose. Some recent studies have underlined the fact that various kinds of parallel processing take place at the same time. After the initial input of data for letter recognition, there is a subsequent phase in which three kinds of processing appear to occur in parallel: (a) continuation of the letter shape recognition, (b) analysis for phonemic structure, and (c) search for semantic meaning. Cohen (1970), following Neisser (1967), discusses clear evidence for this parallel processing in her experiments. Subjects can search word lists simultaneously (a) for words drawn from a particular category, (b) for letters, and (c) for "audioverbal" sounds. Thus the subjects can carry out semantic processing, visual processing, and phonemic processing simultaneously.

Speed reading has been suggested as an extreme example of parallel processing by McLaughlin (1969). For the enthusiastic supporters of speed reading, it is worth mentioning that there is an upper limit to the rate at which college students can read without any drop in comprehension scores. For instance, Jester and Travers (1966) consistently found that peak efficiency on comprehension scores occurred at about only 300 words per minute for either visual or audio-visual presentations on Davis Reading Test, Form 1A.

Physiological factors in verbal comprehension. Semantic processing in the sense of sentence completion is known to be very closely dependent on the reliable functioning of the dominant temporal lobe. In fact, this vocabulary score is reduced in direct relation to the size of the lesion (undertaken for therapeutic reasons) in the dominant temporal lobe (Lansdell, 1968). An important recent finding by Bryden (1970), based on testing 234 children, is that boys who are poor readers are more likely to have a dominant hand which is on the opposite side from their dominant ear. Girls showed this effect only in grade 2.

Context and expectancy effects in reading. Many earlier studies have been devoted to context effects on the perception of verbal stimuli. Such investigations often came from theories of the relation between hypothesis formation and perception. These theories state that the stronger the external expectancy, the less the amount of stimulus information needed externally to confirm it. Conversely, much more information is needed externally to alter a strong internal expectancy (Tulving & Gold, 1968). Ademan and Smith (1971) have noted that expectancy can determine the functional units in perceptual recognition. Spelling-pattern letter strings were recognized more accurately than unrelated letter strings, but the college students acting as subjects had to be expecting the spelling pattern.

Reading as information processing: The eye-voice span. When someone is reading aloud, his eyes travel ahead of his voice; the number of words that intervene between the word being spoken and the word being fixated by the eyes is known as the eye-voice span. It varies with a number of factors, of which age, the phrase structure, and the difficulty of the material are perhaps the most important. Geyer (1966) has suggested that the reading ability of a subject can be measured by the smoothness of his visual behavior during reading aloud. He measured this smoothness for college students by the proportion of all eye movements that were from left to right. He also found that the temporal duration of the eye-voice span was about one second. He derived a Constancy Index which was the mean of the eye-voice span divided by its variability, and he found that there was a high correlation between the Constancy Index and the smoothness of visual behavior for individual subjects. The word span was about three words, one being acquired by the eyes, one held in store for processing, and one being spoken.

We would like to use these findings to examine the performance of children. It would seem possible that a child who has difficulty in verbal coding would have eye-voice spans of one word or less, but durations might be very variable and perhaps thus show a low Constancy Index. On the other hand, children who had difficulty with the motor aspects of speaking might show increased verbal spans in addition to longer durations. Particular attention would be paid to the phrase structure and the familiarity of the material.

Attention

Skill 7. Concentration of Attention, Measured by Brain Wave

Recordings and Comprehension Scores

Mention of physiological factors and expectancy effects brings us to the last skill of attention, which can be measured by neuropsychological methods plus comprehension scores. The two types of brain-wave recordings that would be valuable are (a) the expectancy waves and (b) the evoked potentials.

Expectancy waves. Current research on the slow potential changes by Burian, Gestring, and Haider (1969) have included an analysis of the effects of processing sense-bearing or meaningful words compared with the effects of processing senseless or meaningless words. A series of 30 meaningful words was presented by tape recorder to both ears of 80 normal adults. Each such meaningful word was followed by a light flash. Mixed at random within this series of words was a

second series of 30 meaningless words which were not followed by a light flash. Each meaningful word, provided its meaning was in fact understood, acted as a "warning" stimulus for the expectation of the flash by the subject. There was, therefore, an entirely nonverbal means of recording whether the subject had grasped that this was a meaningful word that would be followed by a bright flash. In all but 20 percent of the subjects, the meaningful words that were understood gave this expectancy wave in the EEG recording. There are many ways in which comprehension of verbal material could be analyzed by this entirely objective procedure.

Evoked potentials. The basic requirement for successful reading is that the child pay attention to what he is reading. Without attention, the most skilled reader will gain nothing from his reading. In order to avoid the difficulties associated with reading itself, a test of attention should usually employ pictures. The child will be shown two pictures, one at a time. One of these should be interesting to him, and the other should be meaningless or dull. While he is looking at both pictures, a light would flash occasionally in the periphery of his field of view. The measures would be: (a) the percentage of time that the child spent looking at each slide rather than away from it; and (b) the size of the evoked potential to the light flash. It is expected that the size of the evoked potential will be inversely proportional to the concentration of the gaze on the picture. Thus, those children who concentrated on the interesting picture would show small responses to the flashes, while their responses to the flashes might be increased when they were shown the dull picture. But the children who did not concentrate on either picture might show about the same moderate-sized responses to the flashes while they were looking at both pictures. By taking a ratio of the evoked potentials during the two pictures, a measure could be obtained for each child that would not reflect individual differences in the absolute sizes of the evoked potentials. Any child who showed ratios for the dull/interesting pictures of less than a certain size could, perhaps, be diagnosed as having difficulty with concentration. This index could be compared to the line-of-sight scores measuring the ability to hold the fixation area. Attempts should also be made to assess the ratio of evoked potentials during the reading of interesting and of dull textual material. Neurophysiological studies of these kinds would resemble investigations of expectancy waves during prolonged alertness studies of attention (Grandstaff & Sheer, 1969).

REFERENCES

Aderman, D., & Smith, E. E. Expectancy as a determinant of functional units in perceptual recognition. Cognitive Psychology, 1971, in press.

Atkinson, R. Computer-assisted learning in action. Proceedings of the National Academy of Sciences, 1969, 63, 588-594.

Atkinson, R. C., Fletcher, J. D., Chetin, H. C., & Stauffer, C. M. Instruction in initial reading under computer control. Technical Report No. 158. Palo Alto, Calif.: Institute for Mathematical Studies in the Social Sciences, Stanford University, 1970.

Atkinson, R. C., & Wilson, H. A. Computer-assisted instruction. Science, 1968, 162, 73-77.

Atkinson, R. C., & Wilson, H. A. (Eds.) Computer-assisted instruction: A book of readings. New York: Academic Press, 1969.

Bay, E. Aphasia and nonverbal disorders of language. Brain, 1962, 85, 411-426.

Bay, E. Aphasia and conceptional thinking. In L. Halpern (Ed.), Problems of dynamic neurology. Jerusalem: Hebrew University, 1963.

Belmont, L., Birch, H. G., & Belmont, I. Auditory-visual intersensory processing and verbal mediation. Journal of Nervous and Mental Disease, 1968, 147, 562-569.

Beritoff, J. S. Neural mechanisms of higher vertebrate behavior. Boston: Little, Brown, 1965.

Blackmer, E. R. Eye-voice span and perceptual-unit size. Unpublished paper, dissertation proposal, October 1970.

Blank, M., & Bridger, W. N. Deficiencies in verbal learning. American Journal of Orthopsychiatry, 1966, 36, 840-847.

Blank, M., & Bridger, W. N. Perceptual abilities and conceptual deficiencies in retarded readers. In J. Zubin (Ed.), Psychopathology of mental development. New York: Grune & Stratton, 1967. Pp. 401-412.

Blank, M., Weider, S., & Bridger, W. N. Verbal deficiencies in abstract thinking in early reading retardation. American Journal of Orthopsychiatry, 1968, 38, 823-834.

Bower, G. H. Organizational factors in memory. Cognitive Psychology, 1970, 1, 18-46.

Bower, G. H., & Springston, F. Pauses as recoding points in letter series. Journal of Experimental Psychology, 1970, 83, 421-430.

Bridger, W. H. Cognitive factors in perceptual dysfunction. In D. A. Hamburg, K. H. Pribram, & A. J. Stunkard (Eds.), Perception and its disorders. Baltimore: Williams & Wilkins, 1970. Pp. 255-265.

Brooks, L. R. Spatial and verbal components of the act of recall. Canadian Journal of Psychology, 1968, 22, 349-368.

Bryden, M. P. Laterality effects in dichotic listening: Relations with handedness and reading ability in children. Neuropsychologia, 1970, 8, 443-450.

Buchsbaum, M., & Fedio, P. Hemispheric differences in evoked potentials to verbal and nonverbal stimuli in the left and right visual fields. Physiology and Behavior, 1970, 5, 207-210.

Burian, K., Gestring, G. F., & Haider, M. Objective speech audiometry? International Audiology, 1969, 8, 387-390.

Butters, N., Barton, M., & Brody, B. A. Role of the right parietal lobe in the mediation of cross-modal associations and reversible operations in space. Cortex, 1970, 6, 174-190.

Butters, N., & Brody, B. A. The role of the left parietal lobe in the mediation of intra- and cross-modal associations. Cortex, 1968, 4, 328-343.

Butters, N., Samuels, I., Goodglass, H., & Brody, B. A. Short-term visual memory and learning deficits in brain-damaged patients. Paper presented at the Annual Meeting of the American Psychological Association, Miami Beach, Florida, September 1970.

Chalfant, J. C., & Scheffelin, M. A. Central processing dysfunctions in children: A review of research. Washington, D.C.: U.S. Government Printing Office, 1969.

Chan, A., & Travers, R. M. W. The effect on retention of labeling visual displays. American Educational Research Journal, 1966, 3, 55-67.

Cohen, G. A comparison of semantic, acoustic, and visual criteria for matching of word pairs. Perception and Psychophysics, 1968, 4, 203-204.

Cohen, G. Some evidence for parallel comparisons in a letter recognition task. Quarterly Journal of Experimental Psychology, 1969, 21-272-279.

Cohen, G. Search times for combinations of visual, phonemic, and semantic targets in reading prose. Perception and Psychophysics, 1970, 8, 370-372.

Cohen, R. L., & Granstrom, K. Interpolated task and mode of recall as variables in STM for visual figures. Journal of Verbal Learning and Verbal Behavior, 1968, 7, 653-658.

Colby, K. M. Computer-aided language development in nonspeaking children. Archives of General Psychiatry, 1968, 19, 641-651.

Critchley, M. Topics worthy of research. In A. H. Keeney & V. T. Keeney (Eds.), Dyslexia: Diagnosis and treatment of reading disorders. St. Louis: Mosby Company, 1968.

Critchley, M. The dyslexic child. London: Heinemann Medical Books, Whitefriars Press, 1970.

Crosby, R. M. N., & Liston, R. A. Reading and the dyslexic child. London: Souvenir Press, 1969.

Crowder, R. G. The role of one's own voice in immediate memory. Cognitive Psychology, 1970, 1, 157-178.

Davis, F. B. Fundamental factors of comprehension in reading. Psychometrika, 1944, 9, 185-197.

Davis, F. B. Research in comprehension in reading. Reading Research Quarterly, 1968, 3, 499-545.

Deno, S. L., Johnson, P. E., & Jenkins, J. R. Associative similarity of words and pictures. AV Communication Review, 1968, 16, 280-286.

Elithorn, A., et al. The effects of the variation of two physical parameters on empirical difficulty in a perceptual maze test. British Journal of Psychology, 1964, 55, 31-37.

Fishman, E. J., Keller, L., & Atkinson, R. C. Massed vs. distributed practice in computerized spelling drill. Technical Report No. 117. Palo Alto, Calif.: Institute for Mathematical Studies in the Social Sciences, 1967.

Forster, K. I. Visual perception of rapidly presented word sequences of varying complexity. Perception and Psychophysics, 1970, 8, 215-221.

Geschwind, N. Brain mechanisms suggested by studies of hemispheric connections. In C. H. Millikand & F. L. Darley (Eds.), Brain mechanisms underlying speech and behavior. New York: Grune & Stratton, 1967.

Geyer, J. J. Perceptual systems in reading--the prediction of a temporal eye-voice span constant. Unpublished doctoral dissertation, University of California, Berkeley, 1966.

Gibson, E. J. Experimental psychology of learning to read. In J. Money (Ed.), The disabled reader. Baltimore: Johns Hopkins Press, 1966.

Goldman-Eisler, F. Psycholinguistics: Experiments in spontaneous speech. New York: Academic Press, 1969.

Gollin, E. S. Developmental studies of visual recognition of incomplete objects. Perceptual and Motor Skills, 1960, 11, 289-298.

Gollin, E. S. Further studies of visual recognition of incomplete objects. Perceptual and Motor Skills, 1961, 13, 307.

Gollin, E. S. A developmental approach to learning and cognition. In L. P. Lipsitt & C. C. Spiker (Eds.), Advances in child development and behavior. Vol. 2. New York: Academic Press, 1965. Pp. 159-186.

Goode, R. M., & Russo, J. E. Computerized system for collecting eye-movement data. Paper presented at the Annual Meeting of the American Psychological Association, Miami Beach, Florida, September 1970.

Goodman, K. S. (Ed.) The psycholinguistic nature of the reading process. Detroit: Wayne State University Press, 1968.

Goodnow, J. J. Auditory-visual integration as a translation problem. Paper presented at SRCD, Santa Monica, March 1969.

Grandstaff, N. W., & Sheer, D. E. Computer analysis of electrical activity in the brain and its relation to behavior. In H. T. Wyis (Ed.), Current research in the neurosciences. Vol. 10. Basel: Karger Press, 1969.

Haber, R. N. Effect of prior knowledge of the stimulus on word-recognition processes. In R. N. Haber (Ed.), Contemporary theory and research in visual perception. Holt, Rinehart, & Winston, 1968. Pp. 764-769.

Haber, R. N. How we remember what we see. Scientific American, 1970, 222, 104-112.

Hackett, M. G. A hierarchy of skills in listening comprehension and reading comprehension. (Doctoral dissertation, University of California, Berkeley) Ann Arbor, Mich.: University Microfilms, 1968. No. 69-14900.

Horowitz, L. M., & Prytulak, L. S. Reintegrative memory. Psychological Review, 1969, 76, 519-531.

Huttenlocher, J. Word-phrase relationship. Science, 1964, 143, 264-265.

Huttenlocher, J. Children's ability to order and orient objects. Child Development, 1967, 38, 1169-1176.

Jester, R. E., & Travers, R. M. W. Comprehension of connected meaningful discourse as a function of rate and mode of presentation. Journal of Educational Research, 1966, 59, 297-302.

Judd, C. H., & Buswell, G. T. Silent reading. Chicago: University of Chicago Press, 1922.

Kaplan, I. T., Carvellas, T., & Metlay, W. Visual search and immediate memory. Journal of Experimental Psychology, 1969, 71, 488-493.

Klatzky, R. L. Interhemispheric transfer of test-stimulus representations in memory scanning. Psychonomic Science, 1970, 21, 201-203.

Klatzky, R. L., & Atkinson, R. C. Memory scans based on alternative test stimulus representations. Perception and Psychophysics, 1970, 8, 113-117.

Kolers, P. A. Reading temporally and spatially transformed text. In K. S. Goodman (Ed.), The psycholinguistic nature of the reading process. Detroit: Wayne State University Press, 1968.

Kolers, P. A. The role of shape and geometry in picture recognition. In B. S. Lipkin & A. Rosenfeld (Eds.), Picture processing and psychopictorics. New York: Academic Press, 1970. Pp. 181-202. (a)

Kolers, P. A. Three stages in reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Harper & Row, 1970. (b)

Lansdell, H. Effect of extent of temporal lobe ablations on two lateralized deficits. Physiology and Behavior, 1968, 3, 271-273.

Lawrence, D. H., & Sasaki, E. H. An N-channel stroboscopic tachistoscope for typewritten stimuli. Behavioral Research Methods and Instrumentation, 1970, 2, 63-65.

Levelt, W. J. M. The scaling of syntactic relatedness: A new method in psycholinguistic research. Psychonomic Science, 1969, 17, 351-352.

Levelt, W. J. M. Hierarchical chunking in sentence processing. Perception and Psychophysics, 1970, 8, 99-103.

Levin, H., Gibson, E. J., & Gibson, J. J. The analysis of reading skill: A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968.

Levin, H., Grossman, J., Kaplan, E., & Yang, R. Constraints and the eye-voice span in left- and right-embedded sentences. Language and Speech, 1971, in press.

Levin, H., & Williams, J. P. Basic studies on reading. New York: Harper & Row, 1970.

Liberman, A. M., Cooper, F. S., Shankweiler, D. P., & Studdert-Kennedy, M. A single acoustic cue carries information in parallel about successive phonemic segments. Psychological Review, 1967, 74, 431-461.

Lott, D., & Smith, F. Knowledge of intraword redundancy by beginning readers. Psychonomic Science, 1968, 10, 49-50.

Lovell, K., & Gorton, A. A study of some differences between backward and normal readers of average intelligence. British Journal of Educational Psychology, 1968, 36, 240-248.

Luria, A. R. Higher cortical functions in man. New York: Basic Books, 1966.

Mackworth, J. F. The duration of the visual image. Canadian Journal of Psychology, 1963, 17, 62-63. (a)

Mackworth, J. F. The relation between the visual image and post-perceptual immediate memory. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 75-85. (b)

Mackworth, J. F. Auditory short-term memory. Canadian Journal of Psychology, 1964, 18, 292-303. (a)

Mackworth, J. F. Interference and decay in very short-term memory. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 300-308. (b)

Mackworth, J. F. Perceptual coding as a factor in short-term memory. Canadian Journal of Psychology, 1966, 20, 18-33.

Mackworth, J. F. Vigilance and habituation. Baltimore: Penguin Books, 1969.

Mackworth, J. F. Vigilance and attention. Baltimore: Penguin Books, 1970.

Mackworth, J. F. Some models of the reading process: Learners and skilled readers. Paper presented to Conference on the Literature Search in Reading, New Brunswick, New Jersey, February 1971.

Mackworth, N. H. A stand camera for line-of-sight recording. Perception and Psychophysics, 1967, 2, 119-127.

Mackworth, N. H. The wide-angle reflection eye camera for visual choice and pupil size. Perception and Psychophysics, 1968, 3, 32-34.

Mackworth, N. H., & Bagshaw, M. H. Eye catching in adults, children, and monkeys: Some experiments on orienting and observing responses. Perception and Its Disorders, 1970, 43, 201-213.

Mackworth, N. H., & Bruner, J. S. How adults and children search and recognize pictures. Human Development, 1970, 13, 149-177.

Mackworth, N. H., Grandstaff, N. W., & Pribram, K. H. Prolonged orientation to pictorial novelty in severely speech-disordered children. Neuropsychologia, 1971, in press.

Mackworth, N. H., & Morandi, A. J. The gaze selects informative details within pictures. Perception and Psychophysics, 1967, 2, 547-552.

Mackworth, N. H., & Otto, D. A. Habituation of the visual orienting response in young children. Perception and Psychophysics, 1970, 8, 173-178.

Marchbanks, G., & Levin, H. Cues by which children recognize words. Journal of Educational Psychology, 1965, 56, 57-61.

Marshall, M., Newcombe, F., & Marshall, J. G. The microstructure of word-finding difficulties in a dysphasic subject. In G. B. Flores d'Arcais & W. J. M. Levelt (Eds.), Proceedings of the Bressanone Conference. Amsterdam: North Holland Publishing Company, 1971, in press.

McCullough, C. M. Responses of elementary-school children to common types of reading-comprehension questions. Journal of Educational Research, 1957, 51, 65-69.

McLaughlin, G. H. Reading at "impossible" speeds. Journal of Reading, 1969, 12, 499-502.

McNeill, D. The acquisition of language: The study of developmental psycholinguistics. New York: Harper & Row, 1970.

Mecham, M. Development of audiolinguistic skills in children. St. Louis: Warren & Green, 1969.

Mehler, J., Bever, T. G., & Carey, P. What we look at when we read. Perception and Psychophysics, 1967, 2, 213-218.

Michon, J. A. Multidimensional and hierarchical analysis of progress in learning. Unpublished paper presented at the Fourth Annual Cognition Symposium, Psychology Department, Carnegie-Mellon University, Pittsburgh, April 1969.

Miller, G. A. Some psychological studies of grammar. American Psychologist, 1962, 17, 748-762.

Mooney, C. M. Age in the development of closure ability in children. Canadian Journal of Psychology, 1957, 11, 219-226.

Mooney, C. M. Recognition of ambiguous and unambiguous visual configurations with short and longer exposures. British Journal of Psychology, 1960, 51, 119-125.

Morehead, D. M., & Ingram, D. The development of base syntax in normal and linguistically deviant children. In papers and reports on child language development, Stanford University, December 1970.

Morton, J. The effects of context upon speed of reading, eye movements and eye-voice span. Quarterly Journal of Experimental Psychology, 1964, 16, 340-354.

Morton, J. A two-hour reading course. Nature, 1966, 211, 323-324.

Morton, J. Interaction of information in word recognition. Psychological Review, 1969, 76, 165-178.

Murdock, B. B. Modality effects in short-term memory: Storage or retrieval. Journal of Experimental Psychology, 1968, 77, 79-86.

Neisser, U. Cognitive psychology. New York: Appleton-Century-Crofts, 1967.

Neisser, U., & Beller, N. K. Searching through word lists. British Journal of Psychology, 1965, 56, 349-358.

Nodine, C. G., & Lang, N. J. The development of visual scanning systems for differentiating words. Developmental Psychology, 1971, in press.

Paivio, A. Mental imagery in associative learning and memory. Psychological Review, 1969, 76, 241-263.

Phillips, J. L., Shiffrin, R. M., & Atkinson, R. C. Effects of list length on short-term memory. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 303-311.

Poppen, R., Stark, J., Eisenson, J., Forrest, T., & Wertheim, G. Visual sequencing performance of aphasic children. Journal of Speech and Hearing Research, 1969, 12, 288-300.

Posner, M. I. Abstraction and the process of recognition. In G. Bower & K. Spence (Eds.), The psychology of learning and motivation. Vol. 3. New York: Academic Press, 1969. Pp. 44-100.

Posner, M. I., Boies, S. J., Eichelman, W. H., & Taylor, R. L. Retention of visual and name codes of single letters. Journal of Experimental Psychology Monograph, 1969, 79, 1-15.

Posner, M. I., & Konick, A. F. Short-term retention of visual and kinesthetic information. Organizational Behavior and Human Performance, 1966, 1, 71-86.

Posner, M. I., & Mitchell, R. F. Chronometric analysis of classification. Psychological Review, 1967, 74, 392-409.

Pribram, K. H. The four R's of remembering. In K. H. Pribram (Ed.), On the biology of learning. New York: Harcourt, Brace & World, 1969.

Pribram, K. H. The biology of mind. Neurobehavioral foundations. In A. R. Gilgen (Ed.), Contemporary scientific psychology. New York: Academic Press, 1970. (a)

Pribram, K. H. Looking to see: Some experiments on the brain mechanisms of attention in perception. In D. A. Hamburg, K. H. Pribram, & A. J. Stunkard (Eds.), Perception and its disorders. Baltimore: Williams & Wilkins, 1970. (b)

Pribram, K. H. The languages of the brain. Englewood Cliffs, N. J.: Prentice-Hall, 1971. (a)

Pribram, K. H. What makes man human. New York: American Museum of Natural History, 1971, in press. (b)

Pribram, K. H., & Broadbent, D. D. Biology of memory. New York: Academic Press, 1970.

Reber, A. S., & Anderson, J. R. The perception of clicks in linguistic and nonlinguistic messages. Perception and Psychophysics, 1970, 8, 81-89.

Reese, H. W., & Lipsitt, L. P. Experimental child psychology. New York: Academic Press, 1970.

Roberts, G. R., & Lunzer, E. R. Reading and learning to read. In E. A. Lunzer & J. F. Morris (Eds.), Development in human learning. New York: American Elsevier Publishing Company, 1968.

Rodgers, T. S. An exploration of psycholinguistic units in initial reading. Technical Report No. 74. Palo Alto, Calif.: Institute for Mathematical Studies in the Social Sciences, Stanford University, 1965.

Rodgers, T. S. Linguistic considerations in the design for the Stanford computer-based curriculum in initial reading. Technical Report No. 111. Palo Alto, Calif.: Institute for Mathematical Studies in the Social Sciences, Stanford University, 1967.

Rosenfeld, J. B. Coding processes in short-term memory. Paper presented at the Annual Meeting of the American Psychological Association, Miami Beach, Florida, September 1970.

Rudel, R. G., & Teuber, H. L. Discrimination of direction of line in children. Journal of Comparative and Physiological Psychology, 1963, 56, 892-898.

Sales, B. D., Haber, R. N., & Cole, R. A. Mechanisms of aural encoding. IV. Hear-see, Say-write, interactions for vowels. Perception and Psychophysics, 1969, 6, 385-390.

Sasaki, E. H. The influence of number and type of targets upon rapid scanning of word lists. Unpublished doctoral dissertation, Stanford University, 1970.

Shepard, R. N., & Metzler, J. Mental rotation of three-dimensional objects. Science, 1971, in press.

Shiffrin, R. M., & Atkinson, R. C. Storage and retrieval processes in long-term memory. Psychological Review, 1969, 76, 179-193.

Singer, H., & Ruddell, R. B. Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970.

Sokolov, E. N. Modeling properties of the nervous system. In M. Cole & I. Maltzman (Eds.), A handbook of contemporary Soviet psychology. New York: Basic Books, 1969.

Spence, K. W., & Spence, T. J. (Eds.) The psychology of learning and motivation: Advances in research and theory. Vol. 2. New York: Academic Press, 1968.

Sperling, G. Successive approximations to a model for short-term memory. Acta Psychologica, 1967, 27, 285-292.

Spring, C. Recognition by dyslexic and normal children. Unpublished doctoral dissertation, Standard University, 1970.

Standing, L., Conezio, J., & Haber, R. N. Perception and memory for pictures: Single-trial learning of 2500 visual stimuli. Psychonomic Science, 1970, 19, 73-74.

Standing, L., Haber, R. N., Cataldo, M., & Sales, B. D. Two types of short-term visual storage. Perception and Psychophysics, 1969, 5, 193-194.

Sternberg, S. Two operations in character recognition. Some evidence from reaction-time measurements. Perception and Psychophysics, 1967, 2, 45-53.

Sternberg, S. Memory scanning: Mental processes revealed by reaction-time experiments. In J. S. Antrobus (Eds.), Cognition and affect. Boston: Little, Brown, 1970.

Taylor, R. L., & Reilly, S. Naming and other methods of decoding visual information. Journal of Experimental Psychology, 1970, 83, 80-83.

Taylor, W. L., Lore, J. T., & Waldman, I. N. Latencies of semantic aphasics, stutterers, and normal controls to cloze items requiring unique and nonunique oral responses. Paper presented at the Annual Meeting of the American Psychological Association at Miami Beach, Florida, September 1970.

Templeton, A. B. (Ed.) Reading disorders in the United States. Washington, D.C.: U.S. Government Printing Office, 1969.

Travers, R. M. W. Perceptual learning. Review of Educational Research, 1967, 37, 599-617.

Tulving, E., & Gold, C. Stimulus information and contextual information as determinants of tachistoscopic recognition of words. In R. N. Haber (Ed.), Contemporary theory and research in visual perception. New York: Holt, Rinehart, & Winston, 1968.

Turvey, M. T., & Egan, J. F. Release from proactive interference in short-term memory as a function of change in visual and phonemic structure and retention interval. Perception and Psychophysics, 1970, 7, 169-172.

Vurpillot, E. The development of scanning strategies and their reaction to visual differentiation. Journal of Experimental Child Psychology, 1968, 6, 632-640.

Wanat, S. Eye-fixation patterning and grammatical structure. In H Levin et al. (Eds.), The analysis of reading skill. Ithaca, N. Y.: Cornell University, 1968.

Wanat, S. Linguistic structure and visual attention in reading. Unpublished doctoral dissertation, Cornell University, 1971.

Wanat, S., & Levin, H. The eye-voice span: Reading efficiency and syntactic predictability. In H. Levin et al. (Eds.), The analysis of reading skill. Ithaca, N. Y.: Cornell University, 1968.

Wardhaugh, R. Reading: A linguistic perspective. New York: Harcourt, Brace & World, 1969.

Weingartner, H. Verbal learning in patients with temporal lobe lesions. Journal of Verbal Learning and Verbal Behavior, 1968, 7, 520-526.

Werner, H., & Kaplan, E. The acquisition of word meanings: A developmental study. Monographs of the Society for Research in Child Development, 1950, 15.

Wheeler, D. D. Processes in word recognition. Cognitive Psychology, 1970, 1, 59-85.

Wickelgren, W. A. Auditory or articulatory coding in verbal short-term memory. Psychological Review, 1969, 76, 232-235.

Wickelgren, W. A. Context-sensitive coding, associative memory, and serial order in speech behavior. Psychological Review, 1969, 76, 1-15.

Wilson, H. A. An investigation of linguistic unit size in memory processes. Technical Report No. 102. Palo Alto, Calif.: Institute for Mathematical Studies in the Social Sciences, Stanford University, 1966.

Yin, R. K. Face recognition by brain-injured patients: A dissociable ability? Neuropsychologia, 1970, 8, 395-402.

Zigler, E., Jones, L. V., & Kafes, P. Acquisition of language habits in first-, second-, and third-grade boys. Child Development, 1964, 35, 725-736.

8-128/ 8-129

SENSORY AND PERCEPTUAL ASPECTS

OF THE READING PROCESS

H. R. Schiffman

Rutgers University

INTRODUCTION

Reading is a complex acquisition comprised of many prerequisite behavioral skills and activities. No doubt the thrust of much of the research on the reading process concerns the delineation of these activities. The many components comprising reading are inseparably related to general sensory or visual, perceptual, memorial, and cognitive processes, and these, in turn, may be divided into subprocesses. It is the concern here to identify and relate a portion of the sensory and perceptual subprocesses that are relevant to the reading process. Although, few, if any, investigators of the reading process would consider the study of the attainment and use of linguistic skills to be of lesser consequence to the acquisition of reading than the study of the workings of the visual system, the major portion of this paper will be devoted to sensory and perceptual mechanisms of the reading process; that is, the set of problems concerned with the accretion and maintenance of potentially informative stimulation from the total energy impinging on a receptor surface or mosaic, and to an extent, with its translation into a cognitive phenomenon. Underlying this informational flow is the consideration that the ability to see or to receive visual input is prerequisite to reading the printed elements which make up words. Moreover, the efficient performance of reading does depend upon many related sensory and perceptual characteristics of the physical input such as form, size and patterning, illumination and contrast, and the manifold features that determine visibility of printed text. The importance of understanding some of the mechanisms of the ocular system as they relate to the reading process is indicated by the obvious sample facts: the eyes must form and focus the image of the printed elements; they must be trained to move effectively and to scan these stationary patterns; and they must operate to attend to or suppress or inhibit certain aspects of the visual field so that a clear view of the text is afforded. Furthermore, certain aspects of the stimulus field are more attractive, have greater priority with respect to stimulus processing, and are more closely linked with organismic factors that control

attention. Appropriately, we shall begin with a sample of the theories and models of attention that may bear on the reading process.

Although there are multiple meanings and usages of the concept of attention (Mostofsky, 1970), we shall treat it as a dynamic concept concerned with the limited selection process that is basic to the reading process; attentional factors perform the functions of bringing sense organs into meaningful contact with stimulus objects and events not previously accessible, or of intensifying stimulation from sources that are already acting on the sense organs. Although these factors serve to augment the inflow of information from particular sources, they must inevitably exclude or attenuate certain stimuli while facilitating the reception of others. Attentional factors thus aid in determining which stimuli will reach the receptors for further processing and which will be disregarded. We are here particularly concerned with those attentional models that deal with the physical features of the stimulus field and the organismic variables that are relevant to an explanation of what the reader effectively focuses on and the nature of the process that allows him to ignore the residue of less important stimuli.

Broadbent

Broadbent has been a major contributor to the theory and research of selective attention, particularly as they relate to the literature on speech perception. From an examination of the conditions that facilitate the damping of a message and the fate of unattended features of the stimulus input, Broadbent has proposed a general theory of selective attention and memory. Basic to his theory is a filter process, corresponding to stimulus analyzers which select or reject messages from the stimulus input. The filter occurs as a central mechanism, intervening between the sensory input, short-term memory store, and long-term memory store. It is set to pass only information from a "channel" or set of "channels" to which it is tuned. Though there have been certain revisions in his basic model (Broadbent, 1967; 1970; Broadbent & Gregory, 1964), a major criticism of the selective-filter model persists; namely, under certain conditions the meaningful content of the presumably rejected or damped message does make an impression. For example, using a dichotic listening situation (an experimental arrangement in which subjects simultaneously listen to two different messages, generally a different one to each ear), Moray (1959) found that material sent to the unattended ear, such as the listener's name, may be heard; moreover, the gender of the speaker's voice and other gross physical characteristics could be detected (Triesman, 1964). Thus, if a portion of the stimulus information from the nonshadowing (unattending) ear reaches the subject's

attention, he must be listening to it, at least in some sense. Although under certain conditions information received by the nonshadowing ear can intrude on the subject's attention and produce a response, there are data indicating that the analysis of the stimulus input is halted prior to the analysis of verbal meaning (Bartz, Satz, Fennel, & Lally, 1967). On the other hand, it has been proposed (Deutsch & Deutsch, 1963) that all stimuli reaching the senses are fully analyzed for meaning. A similar point has been made by Berlyne (1970) and Worden (1966) who argue that the unattended stimulus input must advance far enough into the central nervous system to be registered so that it can be rejected or permit a reversal in the rejection process as soon as a change in the situation warrants. Such is the case in perception of a novel or unique stimulus or in reception of stimulation of especial ecological significance (e.g., presentation of the subject's own name). However, there are still the questions of why so much of the rejected material is not attended to (Neisser, 1967), and why the rejected material, once fully analyzed, is so completely lost that no savings occur in subsequent learning of this material (Moray, 1959).

As an addendum to Broadbent's filter model, mention must be made of Triesman's revision. Triesman (1964) has suggested a "filter-attenuation" model in which the filter serves to attenuate or modulate the information content of the incoming stimuli rather than eliminate or filter it out as Broadbent originally proposed. This implies that when a particular coding response is selected, other coding responses (e.g., messages from the nonshadowing ear) are not completely turned off but may still perform at some minimal level. In this case, presumably filtered stimuli may be still attended to under conditions in which the attenuation is mild or the filter mechanism incompletely operative. A brief citation, particularly relevant to the linguistic context, summarizes her model of selective attention:

> A possible system for identifying words is a hierarchy of tests carried out in sequence and giving a unique outcome for each word or other linguistic unit. . . . The criteria determining the results of the tests would be made more liberal for certain outcomes if favoured by contextual probabilities, by recent use, or by importance. Messages attenuated by the filter (i.e., presented to the unattended ear) would pass the tests only if the criteria had been lowered in their favour and, if not, would pass no further through the hierarchy. This would be more economical than Deutsch's (Deutsch & Deutsch, 1963) full analysis, since most irrelevant words would fail tests early in the hierarchy [Triesman, 1964, p. 14].

Hochberg

Hochberg (1970a) has proposed a model of selective attention in which the phenomena of attention and the phenomena of perceptual organization result from the normal exercise of well-practiced skills that are fundamental to the perceptual process. He proposes that selective attention consists of testing and remembering one set of anticipations rather than another and that perceptual organization arises predominantly from the ways in which such sets of anticipations are structured.

The general structural components of his model of selective attention are (1) analyses of certain immediately available information from the input (e.g., word shape, spatial location); (2) anticipatory encoding, involving the elicitation of a set of expectations about immediately subsequent stimuli (e.g., clues anticipated from context); and (3) a storage component, involving organization; what is encoded as a confirmed expectation is stored, what is not encoded is lost.

Hochberg outlines the task of active reading as an example of the operation of his model. The beginning reader presumably learns to read by putting together a series of letters that are individually fixated, whereas the experienced reader does not necessarily perceive many more letters per fixation. Rather, the practiced reader is responding with a readiness to perceive a word or phrase on the basis of only a few features, with the attempt to confirm a potential word sequence by fixating the array of text as far along as his anticipatory span will allow.

> That is, the task in active reading is to fixate only those parts of the visual array that the reader expects (on the basis of previous semantic and syntactic constraints and on the basis of how words and spaces appear to peripheral vision) and which will enable him to check his guesses about what is being said, and will help him to formulate further anticipations. The better the reader, the more widespread the fixations by which we should expect him to sample the text, and the more likely that morphemes with shapes having only a superficial resemblance to a highly probable word will be encoded as that word [Hochberg, 1970a, p. 117].

This assumes that the human visual system must be able to recognize which features seen in peripheral vision are uninformative with regard to what has already been received and registered and, therefore, do not require specific foveal fixation. Some evidence supporting this assumption has been reported (Mackworth & Bruner, 1970; Mackworth & Morandi, 1967). We shall return to the implications raised

by Hochberg's model in a later discussion of knowledge of language structure in combination with peripheral vision.

Berlyne

Thus far we have not considered any theoretical treatment of attention that focuses primarily on features within the stimulus field, rather than within the organism, as the major determinants of attention. However, because reading does involve, at least at some initial phase, the detection and recognition of graphic symbols, it is appropriate to consider some primary aspects of attention within the physical context.

In large measure, Berlyne (1950, 1951, 1958, 1965, 1966, 1970) has described selective attention in terms of certain physical characteristics of the stimulus field. For example, he considers much of selective perception to be based on spatial location. That is, a proper response is determined by the stimuli impinging on certain receptors, while stimuli striking other receptors do not affect the response. In fact, the role of a filter has been eliminated as an attentional component.

> . . . there is an important difference between exploratory responses and selective attention. The former determine which stimuli shall reach the receptors, so that they discard many stimuli before they can be perceived. Attention, on the other hand, comes into play after the sense organs have been excited and chooses among stimuli that have already been perceived [Berlyne, 1970, p. 33].

Berlyne's treatment of attention lies within a behavior-theory tradition which empirically has led to the practice of utilizing nonverbal forms of behavior. Attention in performance has been relegated to selection among competing stimuli. His method has been to confront the subject simultaneously with several stimuli; characteristically, each of the stimuli is associated with a corresponding motor response, but only one of the responses can be performed, the choice being left free. He argues that by such a method one can investigate the effects of attentional properties of stimuli and, indirectly, factors residing within the organism.

We can only sample from the many kinds of physical characteristics that have been examined by this behavioristic method and demonstrated to affect attention. For example, in a report exploring the effects on attention of intensity or luminous flux, it was found that more responses (hence greater attention-demanding power) occurred to the larger and the brighter of two stimuli (Berlyne, 1950); more responses were made to colored over white figures (Berlyne, 1970); novel

stimuli were found to yield more responses than familiar ones (Berlyne, 1951, 1958), subjects spent more time gazing at the more complex number of a pair of patterns (Berlyne, 1966); the contrast of figures with their background was a critical determinant of selective attention and albedo a secondary determinant in the absence of contrast (McDonnell, 1970).

No doubt many physical characteristics of the stimulus field are potent variables that control and monitor the viewer's attention. Relative brightness, size, shape, contrast, changing light patterns, and, in general, most forms of moving stimuli are physical features that affect attention. Yarbus (1967) has examined attentional components of the scanning process by recording eye movements during the viewing of pictures. He comments that borders, outlines, contours, and, in general, informative features of the stimulus field are particularly attended to. Similarly, Mackworth and Morandi (1967) report that less complex or redundant areas of a picture received much less attention, as measured by the number of ocular fixations, than did unusual or unpredictable areas. Clearly relevant to Berlyne's model is the vast literature on masking (Kahneman, 1968) and related inhibitory visual phenomena, display features such as retinal locus, type size, word shape, line pattern, and other physical factors of the visual field that have been summarized and synthesized by Geyer (1970) and White (1969), for example, and that may directly or indirectly affect attention.

Neisser

Neisser (1967, 1969) treats attention as the allocation of cognitive resources: attention is simply the allotment of analyzing mechanisms to a limited region of the stimulus field. He proposes two systems of processes involving two levels of figural analysis. There are preliminary processes called "preattentive" that refer to a global, wholistic, nondetailed level of operations which serves to construct and segregate figural units and direct further processing. They correspond to the Gestalt "autochthonous forces" and they produce what Hebb (1949) termed "primitive unity." Activity by the preattentive processes forms the figural units that later mechanisms will interpret. They include such activities as, "walking, driving, visual tracking, and other responses that are more literal than categorial, more analog than digital . . . [Neisser, 1967, p. 92]." To this list we add certain preliminary aspects of the ordinary act of reading, such as initially "chunking" the figural unit of a word. Under the assumption that reading does not involve attention to details such as identifying each letter, the utilization of partial cues and fragmentary features may become preattentive with sufficient practice. An interesting point of convergence between Neisser's model and the preceding attentional model

of Hochberg concerns the sensory nature of the preattentive processes. Hochberg (1970a) suggests that:

> . . . the preattentive analyses are most probably extra-foveal although Neisser does not go into that matter, and occur before the irrelevant items are actually fixated (hence, in part, the blurred appearance), while the attended items were brought more closely to the fovea [p. 111].

That is, the preattentive analyses may be performed on peripheral stimulation. Neisser (1969) has recently reported the results from an experiment on a preattentive aspect of selective attention, termed "preattentive vigilance," that support Hochberg's description of the sensory aspect of the preattentive processes. The experiment was modeled after a selective listening experiment (Moray, 1959), using an experimental arrangement in which subjects simultaneously listen to two different messages, generally a different one to each ear. It has been observed that some material sent to the unattending ear, such as the listener's own name, is heard. The assumption of the present experiment was that although ordinary reading is a selective process in that one receives information from the line which one is reading at the moment and ignores adjacent lines which are also visually present, the residue of less important stimulation is determined by a preattentive level of analysis. The basics of the experiment were as follows: subjects were presented with passages from a humorous story that was to be read aloud. The passages were typed in red. Between the lines of the story, however, were strings of random words that were typed in black and with initial capitals. This was done so that the subject's own name could be printed without being conspicuous. The aim of the experiment was to determine whether certain phenomena observed in selective listening would also appear in selective reading: specifically would subjects pick out their own name from the irrelevant material? The results indicated that although the subjects seemed to be paying little attention to the black irrelevant lines, as appraised by comparing reading rates with and without the black lines, about two-thirds noticed their own name the first time it occurred. Neisser concludes that there are preattentive processes in vision analogous to those studied in hearing and, consonant with Hochberg's analysis, they operate by the utilization of peripheral vision.

The second level of analysis, "focal attention," involves more sophisticated processing of the stimuli and is carried out after the global properties from the preattentive process have been established. A by-product of this processing is increased accuracy of a limited region, but it encompasses more; focal attention is a constructive, synthetic activity rather than simply a receptive, analytic one and, as Neisser describes it, it is basic to the reading process.

The dramatic cumulative effect of successive exposures on word recognition demonstrated by Haber and Hershenson (1965) can be cited as an example of the operation of the synthetic aspects of focal attention. In their experiment, Haber and Hershenson used repeated equal tachistoscopic exposures (up to 25 repetitions) of a given word. Subjects were requested to focus their attention and report the individual letters they had seen. The results were clear: successive flashes of the words produced increasingly more correct reports. In one citation, accuracy rose from 40 percent on the first trial to about 100 percent after 10-15 trials. Since subjects focused on individual letters, a fragment or letter synthesized visually on one trial was reconstructed on the next trial, at which time the subject was seeking a different fragment. Thus, more and more fragments were synthesized until every letter appeared.

In his consideration of the attentional factors concerned with the perception of words, Neisser emphasizes that the word is treated in a single act of focal attention rather than as a series of like acts corresponding to the apprehension of individual letters: the perception of the entire word is a product of a figural synthesis.

Fragment Theory of Neisser

Complementing his treatment of attention, Neisser (1967) has offered a basis for the veridical perception of stimuli from less than total stimulation, which he titles "Fragment theory." In brief, recognition occurs with incomplete stimulus information. Neisser argues that certain organismic variables may predispose the reader to perceive one stimulus configuration rather than another. Stimulus recognition does not only depend on the physical features extracted from the input but it also depends upon the kind of stimulus the viewer is prepared to confront: readers tend to see what they expect to see. That is, organismic mechanisms (such as set, familiarity, and context) interact with the stimulus input to augment the formation of a percept. The advantage of context and familiarity to word recognition has been amply demonstrated (e.g., Savin, 1963; Solomon & Postman, 1952; Tulving & Gold, 1963).

A good example of the characteristics of Fragment theory is seen in the examination of tachistoscopic experiments concerning the effect of language frequency on recognition thresholds. When a word is briefly flashed, only a portion of the word may be seen (Haber & Hershenson, 1965; Newbibbing, 1961).

This fragment may be common to a number of words, and if the subject is instructed to guess the word presented, he

> will respond with the word of greatest frequency of occurrence which incorporates the seen fragment. If the stimulus is a low-frequency word, however, guesses to small seen fragments will be high-frequency words and therefore wrong . . . the subject redintegrates the stimulus word from a seen fragment, the size of the fragment required varying as a function of the frequency of the stimulus word [Newbigging, 1961, p. 124].

The compatibility of Fragment theory with Triesman's (1964) probabilistic model of word recognition and particularly with Hochberg's (1970a) model of attention is indicated by some of Neisser's remarks concerning the word-frequency effect:

> Fragment theory circumvents the difficulties of the pure guessing hypothesis by restricting the set of words from which the "guesses" are assumed to be drawn. Instead of coming from the subject's whole vocabulary in accordance with fixed probabilities, responses are limited to the presumably small number of words compatible with some fragment already seen. With this restriction, it becomes statistically possible to create a significant bias toward common alternatives. . . . The evidence is impressive, and it seems certain that subjects use partial cues in the way suggested by fragment theory [Neisser, 1967, p. 117].

DISCUSSION

We must extend Fragment theory beyond the microgenetic paradigm of tachistoscopic experiments to the normal reading process. Perhaps a significant portion of the fragments obtained in the course of reading is received as peripheral stimulation. This has already been suggested by Hochberg (1970a), both in his own theory of attention and in his remarks on Neisser's preattentive process. As a general introduction to the peripheral means offered by the perceptual system for selectively extracting information from the vast amount available in the visual field, we will briefly outline some of the relevant aspects of the visual system and, in a later section, suggest how the peripheral input functions within the reading context.

The retina of man, whose eyes face forward, possesses a special region, the <u>fovea centralis</u>, which has a high density of photoreceptors. It is not a large region; whereas the retina as a whole covers a visual angle of 240°, the fovea subtends an angle of only about 2° (Llewellyn Thomas, 1968). To see a stationary stimulus with a high degree of acuity or detail, a viewer must move his eyes so as to place the image of the stimulus field on each fovea. The ocular-movement system in man is well adapted for acquiring and following a

moving visual target; this requires that the target, if it is to remain in clear focus, must continue to fall on the fovea. For example, Robinson (1968) has described a model of the primate oculomotor system which incorporates four major subsystems that operate toward the acquisition and tracking of moving visual targets on the fovea.

The foveal retina consists of tightly packed photoreceptors called cones, named after their microscopic appearance. Anatomically and functionally, the distribution of cones has been linked with acuity so that maximal resolving power occurs at the fovea, where the distribution of cones is greatest, and gradually diminishes toward the periphery. In other words, visual acuity is directly proportional to the region of the retina stimulated. The synaptic connections associated with cones explains their high resolving power. In the ideal case, cones are connected to their neurons in a one-to-one ratio so that, within limits, adjacent cones can pick up differences in the stimulus array.

The extrafoveal or peripheral portion of the retina, on the other hand, is primarily composed of photoreceptors called rods. Unlike the cones, many rods may connect to the same neuron. Relative to cone connections, the ratio of rods to neurons is very high; in the extreme periphery of the retina, the ratio of rods to neurons may approach 400 to 1 (von Fieandt, 1966). Thus, when light from an image falls on an adjacent group of rods, the resulting stimulation may be summated at a single neuron. This convergence or pooling of impulses yields greater sensitivity (excitation by low energy levels) than do cones but it is accomplished at a cost to acuity.

Although most authorities hold that visual detail is not possible with peripheral vision, functionally, the peripheral retina is extremely effective in conditions of poor illumination; it is also particularly responsive to movement. For example, when parafoveally stimulated by a moving stimulus, we perceive the movement and its direction but we cannot discern its shape; moreover, such movement will initiate a reflex which will rotate the eye by rapid conjugate eye movements so as to align the moving stimulus onto the area of central vision. This will bring into play the highly developed foveal region with its associated central neural network in order to identify the stimulus. Treated in this way the periphery of the retina acts as an early warning mechanism used to rotate the eyes in order to bring the object recognition (fovea) portion of the optical system onto stimuli (Gregory, 1966).

Llewellyn Thomas (1969) has outlined an informational-flow model in which the eye and brain act together to build up a percept. Though it is a model aimed primarily at

searching behavior (radiological search, at that), the structural components lend themselves to the processes involved in perceiving graphic stimuli. According to his model, the input occurs from searching patterns produced by eye movements which take in visual information from the central foveal and especially the peripheral retina.

> The fovea is essential for detailed perception, but the initial detection is often made by the peripheral retina. It functions as a kind of wide-angle early-warning system, and an object focused indistinctly upon it acts as a stimulus, tending to make us turn our eyes to fixate it accurately and study it in detail. Basically, we search by selecting possible targets from among the many poor-quality images falling simultaneously upon the retina away from the fovea. Moreover, a flickering, moving, or suddenly appearing object, seen out of the corner of the eye, can set up an oculomotor reflex, swinging the gaze upon it. A sudden sound can initiate a similar reflex. These are powerful reflexes, for in the primitive world, a slight movement glimpsed from the corner of the eye or a sudden sound might be the first warning of an attack. Appreciation of these basic functions of the peripheral retina suggests that only those people with tunnel vision can hope to carry out a rigid predetermined program in searching . . . [pp. 405-406].

Much of the information reaching the retina is immediately rejected as irrelevant and a great deal more is used and immediately discarded. This occurs by the functioning of a "filter" constituent--a mechanism postulated to eliminate all but a portion of the incoming visual stimuli--similar, in some respects, to the Broadbent (1958) and Berlyne (1970) notions. The filter also serves as the interface between the input and a decisional component of the model. At this level a cortical response determines a decision which may produce output activities such as corrective eye movements and other motor acts. Another set of cortical constituents concerns the retention of a mental image of the stimulus for which the viewer is searching; here we have the memorial components, both long- and short-term memory. According to Llewellyn Thomas, we cannot cease the operation of searching and filtering at will, though with experience and training we may mitigate their effect.

In brief, the model involves information flowing into the brain from the eyes, via a filter, a cortical processing of this information, a resulting series of corrective eye movements, and a fresh flow of information inward; thus, eye and brain communicate with each other in a closed loop to construct a percept. Mention must also be made of a model of pattern perception which attempts to explain how patterns are learned and how these patterns are recognized when subsequently

encountered (Noton, 1970). The essential idea of the model is that each pattern is represented in memory as a network of memory traces recording the features of the pattern and the attentional shifts required to pass from feature to feature across the visual field. These attention shifts may take the form of saccadic eye movements or they may be executed internally. Accordingly, memorizing and recognizing a pattern appear to be closely analogous to memorizing and repeating a conventional sequence of behavior, each being an alternating sequence of sensory and motor behavior. Some data in support of this model have been reported (Noton & Stark, 1971).

However, with regard to reading, the periphery may play a more important role than responding primarily to movement during scanning and searching and in conditions of low illumination. During the performance of reading activity, the eyes are moving from point to point in a relatively organized and measurable manner. The most frequent and major eye movement is the saccade: a very brief, involuntary jump, made by the eye as it moves from one part of the visual scene to another. Since the clarity of print occurs only when the optical image is relatively stationary on the retina, saccadic movements are not likely to provide much information to the reader: the print remains physically stationary but its image is moving past the retina, perhaps reflecting as streaks and blurs. Thus, it is the pauses between saccades, the fixations, that provide the useful imagery to the reader. Since there are normally only several fixations per line, each fixation producing only two or three words with clarity, it is a reasonable possibility that some initial form of graphic detection is made by the peripheral retina. The assumption is that the peripheral retina can provide some clues as to informative aspects of the visual field, laterally displaced from fixation and may even serve to direct saccadic movements whose termini are predetermined prior to actual initiation. A basis for this assumption comes from many diverse sources; for example, in a research report on the sensory processing of the cat (Hubel & Wiesel, 1965), it has been noted that certain cortical cells are directly activated by stimulation of the peripheral retina. Furthermore, the utility of the peripheral retina in man has been given a firm empirical argument within the context of free viewing of pictures (Mackworth & Morandi, 1967). Recording the number of ocular fixations as a function of certain physical characteristics (informativeness-uninformativeness) of the pictorial materials, certain conclusions were clear. Areas that were unusual or unpredictable (informative) received the vast number of fixations relative to redundant or predictable areas. According to the authors, peripheral vision served the function of processing and editing out the redundant stimuli. Of the two stimuli employed in the experiment, three-quarters of the area of one stimulus and nearly two-thirds of the second stimulus were scarcely fixated at all. They observed that

. . . redundant and more predictable features are relegated to the periphery of the retina; the peripheral retina therefore quickly screens off the predictable features and leaves the fovea free to process the unpredictable and unusual stimuli [p. 551].

Similarly, Yarbus (1967), summarizing a vast amount of data relating eye movements to pictorial detail, supports the findings cited above:

Foveal vision is reserved mainly for those elements containing essential information needed by an observer during perception. . . . By means of the fovea centralis, man sees many details only around the point of fixation, i.e., around a point which, as a rule, provides essential information. The lower resolving power of the eye periphery is useful because it enables less essential information to be obtained and facilitates the differentiation between the useful and useless information [p. 196].

Still further sensory data from different sorts of studies indicate the functional utility of the peripheral retina.

In a scanning task using numeric displays, Gould and Schaffer (1965) concluded from their results that the more easily seen aspects of a stimulus field are detected with the same amount of accuracy either in the fovea or in the periphery. When more difficult items are initially detected in the periphery, the eyes are then directed to produce a foveal fixation. In a subsequent study, Gould (1967) examined pattern perception by recording eye movements while subjects scanned for target patterns. He found that some patterns were correctly recognized without foveal fixation. That is, they were discriminated peripherally. From his findings Gould concluded that a function of peripheral detection is not only to indicate the locus of the next fixation but also to signal whether or not a particular pattern requires foveal fixation.

Johnson (1965) has reported that observers with large visual fields require fewer fixations (fixation time remaining constant) to extract the same information in a search task than do observers with small visual fields. Since the most informative stimulation occurs during the fixation pause rather than during the eye movement, it follows that observers with larger visual fields should conduct a more effective visual search than observers possessing a small visual field. Supporting this contention is some evidence that the length of the ocular sweep between eye fixations is shorter for poorer performers in a search task (Boynton, Elworth, & Palmer, 1958). Johnson (1965) also reported that increased size of the visual field accounts for superior search performance. Using acuity rings and silhouettes as the stimuli in the

search task, she found significant negative correlations between search time and measures of peripheral acuity. In brief, observers with larger visual fields manifested more effective search performance than did observers with smaller visual fields. Of considerable interest for instructional aids to the enhancement of searching and scanning are the reports that peripheral acuity for familiar stimuli can be increased with training (Crannell & Christensen, 1955). However, it is not clear whether improvement, with training, of peripheral acuity is a matter of learning to respond to reduced cues or a matter of increase in the size of the visual field (Crannell & Christensen, 1956).

An important contribution to the role of form identification in peripheral vision has been recently reported by Menzer and Thurmond (1970). Shapes (outlined and solid-surfaced metric histoforms and polygons) were used as stimuli in an identification task where choice forms were fixed at 0° and target forms at six points along the horizontal meridian of the peripheral retina (5, 20, 35, 50, 65, and 80° from the fovea). The results indicated that the shape and surface of the forms presented in peripheral vision are both important determinants of form perception. Perhaps the most striking finding was that there was some accuracy in the identification of solid-surface polygons in the far periphery, 80° from the fovea. Combined speed of recognition and error scores indicated that shape is the most salient dimension of a form less than 50° from the fovea, whereas beyond 50° from the fovea, the surface of a form (outlined or solid) is the most salient dimension.

More recently, Kerr (1971) has challenged the classical notion of visual acuity in the peripheral retina which holds that acuity drops rapidly within 5° from the center of the fovea and then continues to drop at a slower rate out to the far periphery (Mendelbaum & Sloan, 1947; Wertheim, 1894). By using a 3° square grating target at four retinal locations along the horizontal meridian of the temporal retina, over a wide range of luminances, for 200 msec, Kerr obtained findings indicating that the previous determinations have underestimated the acuity of the periphery; visual acuities at 10, 20, and 30° from the fovea were two to four times higher than previously reported. No doubt, these higher acuities recorded for the peripheral retina can be attributed to improvements in the control of the experimental conditions of assessing acuity. Clearly, studies such as those outlined above are more than suggestive of the role which the peripheral retina can play in the reading process.

Before pursuing some of the specific informative aspects of reading gained by peripheral vision, it is well to first consider the kinds of psycho-physical clues that exist in graphic materials. In normal reading, a word or phrase is

correctly perceived without the viewer's having to fixate each letter or graphic unit of the line of print as they spatially occur. The well-known error of recognition--the proofreader's error, in which an incorrectly spelled word is perceived as correct--bears out this point. Tachistoscopic experiments have demonstrated that the number of unconnected letters correctly recognized is well below the number of letters recognized when they are grouped into familiar words. As early as 1885, Cattell reported that with an exposure of 10 msec, three to four unrelated letters, two unrelated short words, and four related short words could be correctly recognized (cited in Woodworth, 1938, p. 738). What is perceived from a line of print may depend, in part, upon certain physical features inherent in printed text, as well as the relationships between these features and psychological variables. A number of such features can be enumerated:

1. Word shape. To borrow from Neisser (1967), the words lint and list have the same shape while line and lift do not; it follows that the first pair of words are less distinctive. However, when printed as capital letters, the latter pair of words, LINE and LIFT, manifest the same rectangular shape and lose their distinctiveness. Indeed, when tachistoscopically presented, words printed in capital letters manifest similar shapes and are harder to identify than when presented in lower-case type. The use of this cue to recognition is evidenced by the report of Foote and Havens (1965), who cite that their subjects first identify the shape of a tachistoscopically presented word and then tend to produce the most common word which is compatible with that shape.

2. Spelling patterns. Certain constellations of letters occurring in a given position within a word possess an invariant relationship with a phonetic pattern, i.e., a cluster of letters that corresponds to a sound. Gibson et al. (1962, 1964, 1969) propose that this grapheme-phoneme correspondence defines the smallest component unit in written English. Their research indicates that pronounceable units are more easily recognized under tachistoscopic presentation than are unpronounceable units and it may prove to be an important constituent of normal reading.

3. Word spacing, line pattern, and letter size. There are data that indicate that varying the spacing between words (known to printers as "justification") adversely affects reading ability (Gregory & Poulton, 1970). Alternatives to the traditional arrangement of words in a line across a page, such as using the square span style of text presentation, may enhance the reading speed of certain textual material (Nahinsky, 1956). Finally, the legibility and comprehension of letters and words may be affected by the type size (Poulton, 1959, 1965, 1967a, 1967b, 1969).

4. Letter groups. It may be necessary for the reader to perceive only certain familiar letter groups, dominant letters, only the few letters adjacent to the fixation point as a global unit, or just the first and last letters of a word to perceive what is contained in the whole space of the fixation. This is particularly true for familiar words and clearly is supported by the Cattell-type studies and the Fragment model (Neisser, 1967) described earlier. Obviously, the letter context would enhance the utility of this cue and, in tandem, may potently serve the normal reading process.

5. Context. Though less a physical than a psychological cue, it must be included in any listing of the components of discriminability in reading text. Associations provided by the context in which the word or phrase is imbedded may serve as a distinctive clue for recognition (e.g., Tulving & Gold, 1963). We may also include set and familiarity as serving recognizability in a similar manner to context.

This is only a partial listing; certainly many other psycho-physical variables, such as structural features of the language (e.g., Mehler, Bever, & Carey, 1967), could be introduced as aids to the reading process.

The utility of the peripheral retina in searching activities and in stimulus recognition, coupled with the importance of fragmentary psycho-physical features of printed text for recognition, implies that much of the line of print may be indirectly but effectively perceived; that is, the peripheral retina is utilized by the visual system in normal reading.

An interesting haptic analog to the visual periphery in reading has been noted in the rapid reading of Braille by the blind (Carmichael & Dearborn, 1947). (In the Braille system, various combinations of from one to six dots are used to represent letters and short words. By using his fingers, an experienced Braille reader can read at the rate of 50 words a minute.) Some readers move the "nonreading" hand over the lines not being read in a continuous wandering motion. An explanation for this activity given by Maxfield (1928) is that the nonreading hand serves as a substitute for peripheral vision:

> To most seeing people, and even to many blind people, it is incomprehensible that anyone can read ahead on a lower line with the left hand before the right has finished the preceding line. Nevertheless, it is a fact that many of the best readers do read exactly that way, although some of them do so quite unconsciously. One girl who reads with an unusually high degree of accuracy, speed, and comprehension vowed that she could not possibly read ahead with one finger because her mind could not carry two sets of ideas at the same time. A little later, when this girl

was asked to read some fairly difficult material, she was discovered reading so far ahead on the next line with her left hand that her two forefingers met in the middle of each line.

The Uniform Type Committee found that only fifteen out of 1200 readers went ahead on the next line with the left hand before they finished the preceding line with the right. Twelve of these fifteen were in the faster group of readers, however [pp. 50-51].

Hochberg (1970a, 1970b, 1970c) and Hochberg and Brooks (1970) have also outlined the service the peripheral retina may be to reading:

> Because our eyes register fine detail only within a very small region of the retina (the fovea), we must learn about the visual world by a succession of glances in different directions. Hence, like listening to speech, looking at scenes must occur by a temporal sequence of patterned stimulation. But whereas the listener only has the redundancy of ordered speech or music to guide his anticipations of what the next moment's stimulation will bring, the subject viewing a normal world has two sources of expectations: 1) Like the listener, he has learned something about the shapes to be expected in the world, and their regularities; 2) The wide periphery of the retina, which is low in acuity and therefore in the detail that it can pick up, nevertheless provides an intimation of what will meet his glance when the observer moves his eyes to some region of the visual field. And because such changes in fixation point are executed by saccadic movements, whose endpoints are decided before the movement is initiated, the content of each glance is always, in a sense, an answer to a question about what will be seen if some specific part of the peripherally-viewed scene is brought to the fovea [Hochberg & Brooks, 1970, p. 308].

What likely aids the reader with respect to his peripheral vision is the fact that normal text is highly redundant in many ways so that the reader does not have to focus clearly on every portion of every letter, or word or phrase to "read" the text. According to this theory, the practiced reader's fixations are guided by expectations of what he will find when he looks farther along the page. This is based in part on what is vaguely seen in peripheral vision and on the syntax and the meaning of what has just been read. The skilled reader knows enough about the redundancies of spelling, grammar, the contingencies of language, and the idiom used in the text to make a reasonable guess at how much farther along he should look next in order to test his current expectations and perhaps to formulate new ones. The determinants of fixation based on the syntactic framework

and general linguistic contingencies are termed CSG for cognitive search guidance. Coupled with CSG, the reader can use the information given in his peripheral vision, as modified by CSG, to select the loci in which he should seek successive stimuli. Thus, by use of the information offered by peripheral vision, the reader can anticipate where he should look in order to fixate the most informative portions of the text facing him. The authors term such determinants of fixation PSG for peripheral search guidance. Accordingly, the practiced reader moves his eyes under the combined control of CSG and PSG. It follows, then, that use of the information offered by peripheral vision and contextual redundancies should produce fewer and more widespread fixations.

This model squares with the reading problems of the beginning reader, who likely looks at all or most of the letters confronting him; he is not making use of peripheral vision. It follows that he is less bothered than is the practiced reader when the textual stimuli are degraded, for example, by filling in the interword spaces so as to make the word boundaries indiscriminable when viewed peripherally (Hochberg, Levin, & Frail, 1966). Specifically, when good and poor readers were compared on a task that utilized no interword spaces, the poor (or slow, beginning) reader manifested significantly less reading-rate deficit than did the good (or fast, experienced) reader. It should be noted that when the interword spaces are variable, a reading-comprehension deficit is shown by mediocre readers but not by good readers. Gregory and Poulton (1970) have reported that when the reading comprehension of good and mediocre readers is tested on "justified" text (i.e., text in which both right and left margins are equal, thereby producing irregular and unpredictable spacings between words) versus unjustified text, both composed of short lines of seven words, mediocre readers manifested significant reading-comprehension deficit scores. Furthermore, readers lacking peripheral vision--possessing "tunnel vision"--manifest low reading rates. Experimental evidence in support of this has been reported by Poulton (1962), in which subjects read typescript aloud through a window whose size varied systematically. Errors significantly increased as window size was reduced. A possible explanation for this was the resultant reduction in peripheral vision. Poulton asserts that it is possible to make out in peripheral vision the shape of approaching words; obviously the distance ahead over which this could be accomplished would be limited by the size of the window.

Hochberg and Brooks adequately sum up the implications of this model:

> This picture of skilled reading is one of successive extrapolations, not of information processing, letter by letter. If it is an accurate picture it will explain why

> it appears as though really skilled readers are processing a tremendous amount of information per second; whereas, in fact, they are not--they merely know a great deal about the language and about writers [1970, p. 312].

Gibson (1969) concurs with one of the major points raised in this paper; namely, that a skilled reader takes in more at a single glance by the combined operation of his peripheral vision and his efficacy in grouping word chains and components of phrase structure into single perceptible units. In her discussion of the eye-voice span (the distance that the eye gets ahead of the voice in reading aloud), she comments:

> The optical input can be stopped when the reader reaches a phrase boundary or at any point before or after it. Does the eye reach for the end of a phrase, a structural unit of syntax, as a new fixation begins? The reaching hypothesis is a plausible one, because we suspect that peripheral vision contributes to skilled reading, although we do not know exactly how. When a reader is forced to depend on foveal vision alone . . . he is greatly hampered. It seems as if visual input to the corner of the eye, however poor the acuity of reception, is determining where the next glance is directed [p. 442].

However, she is not a proponent of the viewpoint stressed by Neisser and Hochberg and outlined in this paper that efficient reading is strongly dependent on the reader's ability to utilize his knowledge of the constraints and contingencies of language in order to predict or guess what has not yet been shown from what has been shown.

An examination of the functional utility of fragmentary cues and the informative aspects of the peripheral retina may enable the convergence of several models and theories, and, in general, may aid in synthesizing visual research from several diverse areas. The preceding discussion, incorporating features of the human optical system, has been applied to several of the models described earlier. In particular, the Hochberg (1970a, 1970b, 1970c; Hochberg & Brooks, 1970) and Llewellyn Thomas (1969) models as well as the reaching hypothesis of Gibson (1969) relegate an important aspect of active scanning or reading to the peripheral retina. Neisser's (1967) treatment of attention and the utility of fragmentary cues to reading is not inconsistent with Hochberg's emphasis of the informative aspects given by the peripheral retina. Moreover, the models of Hochberg and Neisser along with Triesman's (1964) probabilistic word-recognition model share the general notion that the reading process consists of the utilization of partial cues in conjunction with the reader's knowledge of grammar, syntax, and general linguistic constraints and contingencies.

Several additional points must be made: concern with the peripheral retina in reading is not a recent consideration; many early sources discuss it (e.g., Carmichael & Dearborn, 1947), and some early data exist. In general, the discussions support its utility while the data are ambivalent (e.g., LaGrone, 1942). Furthermore, a form of reading can occur without a peripheral retina; it is not essential.

The evidence outlined in this paper indicates that a portion of the stimulation provided by the peripheral retina can be utilized for pattern and form discrimination. Less clear is whether or to what extent peripheral stimulation enters in the normal reading process. Certainly, models such as Hochberg's deserve, as well as require, empirical support.

In conclusion, this paper has focused on only one set of problems concerned with the reading process and it has tried to make the following points, by reference to a number of divergent sources: (a) that the peripheral retina plays an important role in the normal reading process by providing direction to successive fixations and fragments or partial cues, and (b) that knowledge of language structure enables the fragments to be productively used in an anticipatory way. Each of these contentions and their interaction should be the concern of further research.

REFERENCES

Bartz, W. H., Satz, P., Fennel, E., & Lally, J. R. Meaningfulness and laterality in dichotic listening. Journal of Experimental Psychology, 1967, 73, 204-210.

Berlyne, D. E. Stimulus intensity and attention in relation to learning theory. Quarterly Journal of Experimental Psychology, 1950, 2, 71-75.

Berlyne, D. E. Attention to change. British Journal of Psychology, 1951, 42, 269-275.

Berlyne, D. E. The influence of complexity and change in visual figures on orienting responses. Journal of Experimental Psychology, 1958, 55, 289-296.

Berlyne, D. E. Structure and direction in thinking. New York: Wiley, 1965.

Berlyne, D. E. Curiosity and exploration. Science, 1966, 153, 25-33.

Berlyne, D. E. Attention as a problem in behavior theory. In D. I. Mostofsky (Ed.), Attention: Contemporary theory and analysis. New York: Appleton-Century-Crofts, 1970.

Boynton, R. M., Elworth, C., & Palmer, R. M. Laboratory studies pertaining to visual air reconnaissance. USAF, WADC TR 55-304, Part III, April 1958.

Broadbent, D. E. Perception and communication. New York: Pergamon Press, 1958.

Broadbent, D. E. Word frequency effect and response bias. Psychological Review, 1967, 74, 1-15.

Broadbent, D. E. Stimulus set and response set: Two kinds of selective attention. In D. I. Mostofsky (Ed.), Attention: Contemporary theory and analysis. New York: Appleton-Century-Crofts, 1970.

Broadbent, D. E., & Gregory, M. Stimulus set and response set: The alternation of attention. Quarterly Journal of Experimental Psychology, 1964, 16, 309-317.

Carmichael, L., & Dearborn, W. F. Reading and visual fatigue. New York: Houghton Mifflin, 1947.

Crannell, C. W., & Christensen, J. M. Expansion of the visual form field by perimeter training. USAF, WADC TR 55-368, October 1955.

Crannell, C. W., & Christensen, J. M. A study of perimeter training with diversified stimuli. USAF, WADC TR 56-63, June 1956.

Deutsch, J. A., & Deutsch, D. Attention: Some theoretical considerations. Psychological Review, 1963, 70, 80-90.

Foote, W. E., & Havens, L. L. Stimulus frequency: Determinant of perception or response? Psychonomic Science, 1965, 2, 153-154.

Geyer, J. J. Models of perceptual processes in reading. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970.

Gibson, E. J. Principles of perceptual learning and development. New York: Appleton-Century-Crofts, 1969.

Gibson, E. J., Bishop, C. H., Schiff, W., & Smith, J. Comparison of meaningfulness and pronunciability as grouping principles in the perception and retention of verbal material. Journal of Experimental Psychology, 1964, 67, 173-182.

Gibson, E. J., Pick, A. D., Osser, H., & Hammond, M. The role of grapheme-phoneme correspondence in the perception of words. American Journal of Psychology, 1962, 75, 554-570.

Gould, J. D. Pattern recognition and eye-movement parameters. Perception and Psychophysics, 1967, 2, 399-407.

Gould, J. D., & Schaffer, A. Eye movement patterns in scanning numeric displays. Perceptual and Motor Skills, 1965, 20, 521-535.

Gregory, M., & Poulton, E. C. Even versus uneven right-hand margins and the rate of comprehension in reading. Ergonomics, 1970, 13, 427-434.

Gregory, R. L. Eye and brain. New York: McGraw-Hill, 1966.

Haber, R. N., & Hershenson, M. Effects of repeated brief exposures on the growth of a percept. Journal of Experimental Psychology, 1965, 69, 40-46.

Havens, L. L., & Foote, W. E. The effect of competition on visual duration threshold and its independence of stimulus frequency. Journal of Experimental Psychology, 1963, 65, 6-11.

Hebb, D. O. The organization of behavior. New York: Wiley, 1949.

Hochberg, J. Attention organization and consciousness. In D. I. Mostofsky (Ed.), Attention: Contemporary theory and analysis. New York: Appleton-Century-Crofts, 1970. (a)

Hochberg, J. Attention in perception and reading. In F. A. Young & D. B. Lindsley (Eds.), Early experience and visual information processing in perceptual and reading disorders. Washington, D.C.: National Academy of Sciences, 1970. (b)

Hochberg, J. Components of literacy: Speculation and exploratory research. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. (c)

Hochberg, J., & Brooks, V. Reading as an intentional behavior. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970.

Hochberg, J., Levin, H., & Frail, C. Studies of oral reading: VII. How interword spaces affect reading. Unpublished manuscript, Cornell University, 1966.

Hubel, D. G., & Wiesel, T. N. Receptive fields and functional architecture in the two non-striate areas (18 and 19) of the cat. Journal of Neurophysiology, 1965, 29, 229-289.

Johnson, D. M. Search performance as a function of peripheral acuity. Human Factors, 1965, 7, 527-535.

Kahneman, D. Method, findings, and theory in studies of visual masking. Psychological Bulletin, 1968, 69, 408-425.

Kerr, J. L. Visual resolution in the periphery. Perception and Psychophysics, 1971, 9, 375-378.

LaGrone, C. W. An experimental study of the relationship of peripheral perception to factors in reading. Journal of Experimental Education, 1942, 11, 37-49.

Llewellyn Thomas, E. Movements of the eye. Scientific American, 1968, 219, 88-95.

Llewellyn Thomas, E. Search behavior. Radiologic Clinics of North America, 1969, 7, 403-417.

Mackworth, N. H., & Bruner, J. S. How adults and children search and recognize pictures. Human Development, 1970, 13, 149-177.

Mackworth, N. H., & Morandi, A. J. The gaze selects informative details within pictures. Perception and Psychophysics, 1967, 2, 547-552.

Maxfield, K. E. The blind child and his reading. New York: American Foundation for the Blind, 1928.

McDonnell, P. M. The role of albedo and contrast in a test of selective attention. Perception and Psychophysics, 1970, 8, 270-272.

Mendelbaum, J., & Sloan, L. L. Peripheral visual acuity. American Journal of Ophthalmology, 1947, 30, 581-588.

Mehler, J., Bever, T. G., & Carey, P. What we look at when we read. Perception and Psychophysics, 1967, 2, 213-218.

Menzer, G. W., & Thurmond, J. B. Form identification in peripheral vision. Perception and Psychophysics, 1970, 8, 205-209.

Moray, N. Attention in dichotic listening: Affective cues and the influence of instructions. Quarterly Journal of Experimental Psychology, 1959, 11, 56-60.

Mostofsky, D. I. Attention: Contemporary theory and analysis. New York: Appleton-Century-Crofts, 1970.

Nahinsky, I. D. Typographical arrangements and span of visual comprehension. Journal of Applied Psychology, 1956, 40, 178-180.

Neisser, U. Cognitive psychology. New York: Appleton-Century-Crofts, 1967.

Neisser, U. Selective reading: A method for the study of visual attention. Paper presented at the 19th International Congress of Psychology, London, 1969.

Newbigging, P. L. The perceptual redintegration of frequent and infrequent words. Canadian Journal of Psychology, 1961, 15, 133-142.

Noton, D. A theory of visual pattern perception. IEEE Transactions on Systems Science and Cybernetics, SSC-6, 4, October 1970.

Noton, D., & Stark, L. Scanpaths in eye movements during pattern perception. Science, 1971, 171, 308-311.

Poulton, E. C. Effects of printing types and formats on the comprehension of scientific journals. Nature, 1959, 104, 1824.

Poulton, E. C. Peripheral vision, refractoriness and eye movements in fast oral reading. British Journal of Psychology, 1962, 53, 409-419.

Poulton, E. C. Letter differentiation and rate of comprehension in reading. Journal of Applied Psychology, 1965, 49, 358-362.

Poulton, E. C. Searching for newspaper headlines printed in capitals or lower-case letters. Journal of Applied Psychology, 1967, 51, 417-425. (a)

Poulton E. C. Skimming (scanning) news items printed in 8-point and 9-point letters. Ergonomics, 1967, 10, 713-716. (b)

Poulton, E. C. Skimming lists of food ingredients printed in different sizes. Journal of Applied Psychology, 1969, 53, 55-58.

Renshaw, S. The visual perception and reproduction of forms by tachistoscopic methods. Journal of Psychology, 1945, 20, 217-232.

Robinson, D. A. Eye movement control in primates. Science, 1968, 161, 3847, 1219-1224.

Savin, H. B. Word frequency effect and errors in the perception of speech. Journal of the Acoustical Society of America, 1963, 35, 200-206.

Solomon, R. L., & Postman, L. Frequency of usage as a determinant of recognition thresholds for words. Journal of Experimental Psychology, 1952, 43, 195-201.

Triesman, A. M. Selective attention in man. British Medical Bulletin, 1964, 20, 12-16.

Tulving, E., & Gold, C. Stimulus information and contextual information as determinants of tachistoscopic recognition of words. Journal of Experimental Psychology, 1963, 66, 319-327.

Uttal, W. R., & Smith, P. Recognition of alphabetic characters during voluntary eye movement. Perception and Psychophysics, 1968, 3, 257-264.

von Fieandt, K. The world of perception. Homewood, Ill.: Dorsey Press, 1966.

Wertheim, T. Über die indirekte Sehschërfe Zeitschrift für Psycholog. und Physiolog. Sinnesorg., 1894, 7, 172-187.

White, M. J. Laterality differences in perception: A review. Psychological Bulletin, 1969, 72, 387-405.

Woodworth, R. S. Experimental psychology. New York: Henry Holt, 1938.

Worden, F. G. Attention and auditory electrophysiology. In E. Stellar & J. M. Sprague (Eds.), Progress in physiological psychology. Vol. 1. New York: Academic Press, 1966.

Yarbus, A. L. Eye movements and vision. New York: Plenum Press, 1967.

LINGUISTIC STRUCTURE IN READING: MODELS FROM THE RESEARCH OF PROJECT LITERACY

Stanley F. Wanat

Stanford University

Project Literacy, under the direction of Harry Levin at Cornell University, sponsored research on basic reading processes by a number of psychologists, educators, and linguists. Much of the work accomplished was presented in unpublished Project-Literacy Reports that appeared from 1964 to 1968, in many published articles, and in a book edited by Levin and Williams (1970).

MODEL I: READING AS DECODING TO SPEECH

E. Gibson (1965) maintains that "reading entails decoding to speech. Letters are, essentially, an instruction to produce a given speech sound." Later, she stated this view in the following way: "Reading is a second-order symbol system which decodes to speech [E. Gibson, 1970]." Publications of the Gibson group suggest the model of the reader as "speaker, then hearer." The task of the reader is to translate graphemes into phonemes. This is the task particular to reading. After decoding to speech has been accomplished, comprehension processes associated with speech comprehension are brought into play.

The pronounceability studies of the Project-Literacy group support this model of the reader. In a study of the perception of real words and pseudo words, Levin and Biemiller (1968) analyzed oral reading into "the process of decoding and matching to auditory memory." Biemiller and Levin (1968) found that "the harder a word is to pronounce, the longer is the interval from the exposure of the word to the verbal response." They further argue that

> the correct recognition of words at threshold, the level of the threshold, and the time it takes to read when the stimulus is available . . . have a common process at their base: the decoding to sound and, in the case where the procedure requires a verbal response, the private rehearsal

of the decoded sound sequence against an experience-generated schema of acceptable sounds.

Biemiller and Levin say that this description holds for adults and children. According to their interpretation, the major point is that the correct recognition of words depends upon decoding to sound. It is important to note that their assertion is that the output of the decoding process is "speech"--not "language." The reading process is mediated by speech, and the decoding-to-speech group of studies rejects the view that there is a more direct form of apprehension. A similar view was put forth by Huey (1901). He stated that he had encountered very few purely visual readers and that most utilized auditory-motor mediation. Bever and Bower (1966), however, claimed that there are two main types of readers--auditory and visual.

In a study of the role of grapheme-phoneme correspondences in words, Gibson, Pick, Osser, and Hammond (1962) found that spelling-to-sound correlations constitute important language units in reading. Letter sequences constructed according to the rules of invariant spelling-to-sound correlation were perceived more accurately than sequences without invariant spelling-to-sound prediction. In a subsequent study, Gibson, Osser, and Pick (1963) found that familiar three-letter words were spelled more accurately than nonword trigrams after tachistoscopic viewing. Also, pronounceable nonword trigrams were perceived more accurately than unpronounceable trigrams. They concluded that rules for grapheme-phoneme correspondence are inferred from real words already encountered, and that these rules organize larger units for perception. Bishop (1964) concluded that knowledge of grapheme-phoneme correspondences was not necessary to read familiar words but was necessary to transfer to new words.

If reading is, indeed, mainly a process of decoding to speech, it is logical that knowledge of grapheme-phoneme rules be seen as a critical component of the reading process. Hockett (1963) holds that the basis of literacy is the association between spelling and sound built up by the reader. Venezky (1963) holds that learning to read is learning to correlate graphemes and phonemes. Thus, the reading process is concerned with what linguists call surface-structure phenomena. Chomsky and other linguists reject this conception of reading. N. Chomsky (1970), for example, asserts that English orthography provides a near-optimal representation of underlying meaning relations; that is, the orthography provides direct cues to meaning (deep structure). An example provided by Chomsky to illustrate this representation of meaning relations in the orthography follows: Consider the words "telegraph," "telegraphic," "telegraphy." The consistent spelling of "telegraph" in all three words shows the underlying meaning relations among them. If the spelling were a sound-by-sound

transcription, the spelling of the initial three syllables would have to be different to show differences in the pronunciation. Since it is not, the reader must learn that the first nine letters in each of the words have different spelling-to-sound mappings but identical spelling-to-meaning mappings.

It has already been noted that, in opposing the conception of reading as decoding to speech, Bever and Bower (1966) argue that there are two kinds of reading: one mediated by speech and the other directly visual. Gibson, Shurcliff, and Yonas (1970) found that deaf subjects were more successful in reading pronounceable than unpronounceable word strings. Since these subjects were either congenitally deaf or else had become deaf at a very early age, they could not be utilizing the relatively greater ease with which pronounceable letter strings decode to speech. Consequently, ease of decoding to speech could not have been the factor that caused the deaf subjects to perform better on some of these letter strings than on others. Thus, the perceiver (whether he can or cannot hear) may be utilizing orthographic constraints instead of, or in addition to, spelling-to-sound mapping. Additional evidence for the use of orthographic constraints can be found in Smith's (1968) analysis.

MODEL II: READING AS INFORMATION SEARCH

A second model of the reading process is based on the interpretation of reading as a search for information (Hochberg, 1970). This view parallels Goodman's (1970) description of reading as the reduction of uncertainty. J. Gibson (1966) also believes that reading is a search for information, with the information being mediated by the language and by the spelling system. Hochberg (1970) distinguishes between reading as translating graphemes into phonemes and reading as a search for information. He conceptualizes the task of the reader as that of extracting the information necessary for comprehension from a display of information that is largely irrelevant and redundant. If the reader has to extract the necessary information from a display containing irrelevant and redundant information, an efficient processing strategy would entail sampling of the text.

One of the clearest indications that the mature reader does, indeed, attend to less than the total available information in word recognition and in the reading of sentences is the fact that very proficient readers can read materials without detecting errors like letter substitutions, transpositions, omissions, or additions (Pillsbury, 1897). Function words can be repeated (e.g., the the) or omitted entirely without the reader's noticing the error. If the total available information were being processed, such failures to notice errors would

occur less frequently. Empirical proof that the mature reader does not process all of the available information is reported by Kolers (1970). He found that if the reader was forced to adopt a letter-by-letter strategy, his rate dropped to about one-tenth of his normal reading speed. Smith (1968) found that in the identification of tachistoscopically presented letter strings, readers used two sources of partial information. Both the distinctive features of the individual letters and the orthographic constraints in the letter string served to narrow the range of responses.

The relationship between eye movements and meaning provides evidence about the interaction between the decoding process and what the text means to the reader. Many years ago, Woodworth (1938) investigated this matter. He asked: "Do the fixation points favor any particular sorts of words?" His analysis of the available research (which he described as being "indeed rather scanty") indicated that the reader's difficulties might be traced to such factors as an unfamiliar word, a word used in some other than its common conversational meaning, an ambiguous word not sufficiently prepared for by the context, or a superfluous word from the reader's point of view. Woodworth's analysis did not categorize words that caused difficulties in reading in terms of a linguistically defined frame of reference.

In an experimental study of eye-fixation patterning in reading, Wanat (1971) found that there was significant variability in the amount of visual attention allotted to different areas of a sentence. Thus, the time spent looking at a sentence is selectively allocated to different parts. This selectivity operates with respect to the numbers of both forward and regressive fixations. Wanat found that the main verb is a major factor in determining the reader's allocation of visual attention.

Greenberg (1970) used a same-different sentence-judging task to see if the reader attended to all of the information in the sentence in the same way. The reader's task was to report whether two sequentially presented sentences were identical or whether they were different. Greenberg found that differences in the sentences' main verbs were easiest to perceive while differences in prepositions were hardest to perceive. Noun differences were intermediate in difficulty. These variations in the error rates for different word categories indicate that all of the information in the text is not processed uniformly. Rather, some areas of the text are sampled densely, while other areas are hardly processed at all. The Wanat and Greenberg data parallel Gladney and Kralee's (1967) finding that tampering with the verb interferes most with fluent processing in reading. The importance of the sentence verb is also indicated in Fodor, Garrett, and Bever's (1968) finding that the nature of the complement structure of the verb affects ease of processing.

The preceding studies have dealt with text sampling by mature readers. Following are some studies concerned with text sampling by beginning readers. Weber (1970) analyzed the oral-reading errors of children who were learning to read and found that in some cases the subjects depended more on context cues while in others they depended more on stimulus cues. The presence of an error in itself shows that all of the available information is not being accurately processed. Differences in the dependence on context cues and stimulus cues imply that some of the information is not being attended to. In another study of beginning readers, Marchbanks and Levin (1965) found that the first letter of a word was the most important cue to word recognition. The last letter was the second most informative cue. The middle of the word was the third most relevant cue. Word shape was the least-used cue.

Given the fact that a reader selectively allocates his attention to the text, a model of the reading process must incorporate means for locating potentially informative areas and for deciding on the informativeness of a particular item. This particular aspect of the model is similar to the "tagging" process in Venezky and Calfee's (1970) model. The search-for-information model must include components that can process the different kinds of cues present in the text. These cues are divided into three main categories by Williams and Levin (1967): grapheme, grapheme-phoneme correspondence, and context.

Grapheme cues have been the subject of many research studies, including those of E. Gibson, J. Gibson, Pick, and Osser (1962) and E. Gibson, Osser, Schiff, and Smith (1963). They dealt with the perception of distinctive features of letters. Sorenson (1968) suggested that elements of template matching may have to be included in the process of letter perception. Grapheme-phoneme correspondences and orthographic constraints have already been mentioned in this paper.

The role of interword spaces as cues in reading has been investigated by Hochberg, Levin, and Frail in unpublished studies. They found that when they filled in interword spaces, the absence of cues to word boundaries interfered with fluency of reading in older children but had no adverse effect on the reading of younger children. The former were processing large units while the latter processed letter by letter so that the removal of word boundaries had little effect. Levin and Jones (1968) showed that it was the loss of word-boundary cues and not the confusion of the space-filler symbol with other letters that interfered with the reading fluency of the older children. Meltzer and Herse (1969) found that children gradually eliminate a variety of cues before discovering that interword spaces are cues to word boundaries. This finding suggests that a model of the reading process may have to provide for a shift from one kind of structural cue to another on the part of readers.

Word length is a cue to the kind of information in the word (Hochberg, 1970). Goldman-Eisler (1969) found that informativeness was directly related to word length and that cognitive (as opposed to grammatical) pauses in spontaneous speech were related to the informativeness of the word following the pause. Longer words require more processing, perhaps because they are more informative.

The use of parts of words as cues has already been described in this paper (Marchbanks & Levin, 1965; Weber, 1970). Williams, Blumberg, and Williams (1969) used the Marchbanks-and-Levin technique with disadvantaged kindergartners with no previous training in reading and found that no cue was preferred. They found that half of the adults whom they also tested used a decoding-to-speech procedure; the other half matched overall word shapes. Levin and Cohn (1968) showed that the same reader uses processing units of different sizes as his reading task changes. These findings suggest that there may be no one model of the reading process, just as there may be no one grammar of a language.

That word categories serve as cues for the reader has been shown in studies already described (Fodor, Garrett, & Bever, 1968; Gladney & Kralee, 1967; Greenberg, 1970; Venezky & Calfee, 1970; Wanat, 1971). Investigating how subjects read geometrically transformed text, Kolers (1970) found that when they made mistakes in reading words, they tended to substitute incorrect words of the same parts of speech.

The place of context clues in reading has been discussed by Goodman (1970), Kolers (1970), and Weber (1970). The inverse relationship between context and stimulus information in reading has been reported by Brown (1970) and Tulving and Gold (1963).

Gibson (1970) noted that a single letter can be perceived more easily if it is presented in a word than in isolation. Levin and Ford (1968), Levin, Ford, and Beckwith (1968), and Ford and Levin (1968), in studies of the perception of homographs presented either with or without semantic or syntactic frames, showed that context facilitated perception. It appears that the context served as an additional source of partial information to limit uncertainty and thus facilitated the reader's perception. Lawson (1961) found that greater contextual constraint (predictability) increased the amount of information in the eye-voice span. Morton (1964) showed that greater contextual constraint increased the size of the eye-voice span, increased the speed of reading aloud, decreased the number of oral reading errors, and decreased the numbers of both forward and regressive eye movements. Morton also found that good readers are able to utilize more contextual constraint than poor readers. A model which describes reading as the search for information

must incorporate components to account for the different kinds of cues mentioned above.

Hochberg (1970) and Hochberg and Brooks (1970) specifically postulated two components of the reading process--Cognitive Search Guidance (CSG) and Peripheral Search Guidance (PSG)--which direct visual attention and which are partially determined by internalized rules of linguistic structure. PSG depends on cues like word boundaries and word length. The use of PSG in the scanning of pictorial displays was demonstrated by Mackworth and Morandi (1967) and Mackworth and Bruner (1967). They found that the lawfulness of the relations (constraints) between different areas of the pictorial display permitted the viewer to process less informative areas in peripheral vision. The relationship that Mackworth found between informativeness and scanning of pictorial displays parallels the relationship that Project-Literacy research workers found between informativeness and the reader's scanning behaviors. CSG is the other factor that determines the reader's visual search. It includes the reader's interests, his general knowledge, and his intuitive knowledge of linguistic structure.

A modification of the search-for-information model is the view that reading is a search for units. That is, the perception of language in reading is the perception of linguistic signs--"psychic entities with two sides," to borrow Saussure's (1959) terminology. At one level, the unit is the simultaneous bundle of distinctive features that define a letter. At another level, it is an invariant spelling-to-sound relationship. At still another level, it would be the distinctive semantic and syntactic features that define a particular kind of sentence constituent. Some of the Project-Literacy reports have dealt with the nature of the processing unit in reading. Eye-voice span (EVS) studies shed light on the relationship between grammatical structure and the information chunk picked up and processed by the reader. The EVS measure is obtained by obscuring the text from the subject's view when his voice reaches a predetermined word in oral reading. The subject is then asked to report all the words that he saw but had not had a chance to say aloud. The number of words correctly reported is his EVS for that particular instance. Levin and Turner (1968) found that the EVS is not a fixed number of words but varies to coincide with phrase boundaries. Their results parallel Schlesinger's (1969) finding that readers pick up and process phrase units. This tendency for the reader to chunk a sentence into phrase units is characteristic of mature readers but not of beginning readers. Thus, the grammatical structure of the sentence determines the unit processed by the mature reader.

The role that grammatical structure plays in the reader's parsing of the textual materials has also been investigated from the point of view of the reader's overt scanning

behaviors. Judd and Buswell (1922) maintained that numerous irregular eye movements indicate that the reader is trying to break the material up into units. In their experimental procedure, they did not, however, systematically vary the nature of the linguistic elements to measure their effect on eye movements. Later studies (e.g., Levin & Turner, 1968; Schlesinger, 1969) have shown that a reader's information processing reflects linguistic units. Mehler, Bever, and Carey (1967) formulated the general rule that the reader fixates on the first half of each linguistically defined immediate constituent. Their generalization was an important step beyond the instrumentally refined but linguistically naive studies of earlier research workers in the field. There are, however, some major difficulties with their study. First, they discarded approximately half of their data. A case in which the reader had to fixate many points suggests the presence of factors in the sentence which made it difficult to process; yet the fixation of many points served as a basis for discarding the record. Second, their technique took into account only whether or not an area was fixated. They did not differentiate between forward fixations and regressions. Thus, there was no way to determine whether an area was regressed to or from. Third, their procedures failed to take into account the duration of a fixation. It is impossible to determine from their data whether some areas took more time to process than others. Finally, they used sentences that were ambiguous. Since relatively few sentences encountered in normal reading are ambiguous, this characteristic of their materials limits the generalizability of their findings.

In another examination of the relationship between eye movements and the nature of the textual materials, Kennedy (1967) found that regressive eye movements in reading tend to take place within, rather than across, major sentence constituents. The probability of a regression occurring across a constituent boundary was inversely related to the strength or primacy of that boundary. For example, a regressive eye movement was more likely to occur across a relatively weak constituent boundary (such as that between an adjective and the following noun) and much less likely to occur across a relatively strong constituent boundary (such as the major sentence break between the subject phrase and the predicate phrase). Thus, the linguistically defined primacy or importance of a constituent structure boundary is an index to the likelihood that a regression will cross it. There are two limitations in Kennedy's study. First, the characteristics of the readers are not known. It is, therefore, impossible to define the population to which his results are generalizable. Second, his findings are restricted to only one aspect of the reader's overt scanning behaviors.

In a study related to the reports by Mehler, Bever, and Carey (1967) and Kennedy (1967), Wanat (1971) found that

manipulations of a sentence's immediate constituent analysis appeared to affect forward eye-fixation patterning. Manipulations in the structural predictability of grammatical units within the sentence, while the immediate constituent analysis was held constant, appeared to affect regressive eye-fixation patterning. These results suggest that the reader is searching for processing units and that these units are determined by the phrase structure of the textual materials he is reading.

MODEL III: READING AS ANALYSIS BY SYNTHESIS

Levin and Kaplan (1968) suggested an analysis-by-synthesis model (Neisser, 1967) as a possible explanation for their results in a study of the relationship between linguistic structure and the reader's information-pickup and processing behaviors. Later, Levin and Kaplan (1970) detailed a model of the reading process which incorporates (a) hypothesis formation and (b) confirmation or disconfirmation of the hypothesis as major components. Levin and Kaplan (1970) assert, as do Wanat and Levin (1970), that where the reader's initial hypothesis is confirmed by sampling farther into the sentence, processing is more fluent. Where his initial hypothesis is disconfirmed, processing breaks down because the reader may have to regress to recheck either the preceding context or the stimulus, or he may have to sample more densely to resolve the conflict between perceived context information and perceived stimulus information, or he may have to reformulate his hypothesis. This third model of the reading process suggests that greater efficiency in reading is characterized by the operation of reader expectations (or response biases) and the confirmation that these expectations are correct. Analysis-by-synthesis models were adapted to reading from earlier application in the explanation of speech perception (Halle & Stevens, 1964). There are a number of cases in which models of reading and components of reading models parallel models of speech perception. Jakobson, Fant, and Halle (1969) discuss some of the effects of perceiver expectations on speech perception, and as will be discussed shortly, reader expectations are seen to be an important part of Model III. Also, Gibson explicitly based her theory of distinctive features in letter perception on Jakobsonian distinctive-feature analysis of speech. Such parallels between reading and speech perception and the previously mentioned parallels between the scanning of textual and pictorial displays are, of course, to be expected, since reading entails both linguistic and visual processes.

In discussing hypothesis formation, the first component in this model, the reader's expectations or "response biases" (Hochberg, 1970), are important. Gibson (1970) claims that "the information taken in during a fixation increases as reading skill increases." Hochberg (1970), however, would

argue that the mature reader's increase in proficiency is not due to an ability to pick up more information *per se*, but rather to an ability to respond as if he had picked up more information. That is, given the same amount of information, the better reader is the one who is a shrewder guesser. Essential to a model of the reading process that includes hypothesis formation (or reader expectations or response biases) is the view that the reader's previous linguistic and nonlinguistic experiences in his day-to-day life have programmed him to respond in certain ways, given certain kinds of partial information.

Five research techniques have been employed by the Levin group to shed light on the hypothesis-formation component of the reading process. The first technique is an attempt to describe part of the linguistic program that forms the basis for the reader's expectations about the structure of the textual materials. This technique attempts to characterize the reader's intuitive knowledge of the patterning of sentence constituents. The Levin group was interested in how the reader applies his knowledge of the language to the reading task. To study this, they utilized measures of within-sentence structural predictability for different patterns of constraints in active and passive sentences (Clark, 1965). Such measures of structural predictability can be obtained by using a modified cloze procedure in which subjects are asked to complete sentences that have had certain constituents deleted. The way in which the constituents that are present determine the constituents that are filled in shows the contingencies or constraints between various sentence parts. Levin, Grossman, Kaplan, and Yang (in press) extended Clark's active-passive findings to left-embedded (subject-modifying) and right-embedded (object-modifying) sentences. They found that a right-embedded sentence with the embedding deleted was quite likely to be filled in as a right embedding. A similar left-embedded sentence frame was much less likely to be filled in as a left embedding. If the subject was asked to complete a sentence frame in which either a right or left embedding was possible, a right embedding was much more likely than a left embedding. Levin (1967) employed a different technique to explore the reader's expectations about the patterning of sentence constituents in the case of two kinds of passive sentences (agent-included and agent-deleted). He presented both forms to the subject and asked him to choose which sounded better or more natural. Agent-included forms were selected as more natural twice as often as their agent-deleted counterparts. From their first research technique, the Levin group had data on three different sets of sentence types (active/passive; left embedded/right embedded; agent-included passive/agent-deleted passive). These data provided a measure of within-sentence structural predictability and of the reader's knowledge of these patterns of constraints.

The second research technique that the Levin group employed was measuring the size of the unit picked up by the reader. The reader's eye-voice span was the dependent variable, and the predictability, or expectedness, of a particular kind of sentence context was the independent variable. In one experiment in this series, Levin and Kaplan (1968) found that the reader had a longer eye-voice span in the area following a passive verb than following an active verb. Clark (1965) had found the passive to be more constrained or predictable in this area. Levin and Kaplan's (1968) study demonstrated that greater constraints (or predictability) between sentence constituents resulted in more efficient reader processing. They reasoned that knowledge of these constraints is internalized by the reader, and these constraints determine what he expects to find in the structure of what he is reading. Another eye-voice-span study (Levin, Grossman, Kaplan, & Yang, in press) in this series measured the reader's eye-voice span on left-embedded and right-embedded sentences. The modified cloze procedure discussed earlier had shown that the right embedding is much more predictable. Their eye-voice-span experiment showed that the more predictable or expected form resulted in a larger eye-voice span.

Also utilizing the eye-voice-span technique, Wanat and Levin (1968, 1970) presented two different words within identical sentence contexts. The context led the reader to expect a word with a particular kind of structural description (i.e., an underlying agent in a passive sentence), but did not lead him to expect a particular word. The kind of structural difference which they employed was similar to the "John is easy/eager to please" distinction discussed by N. Chomsky (1964, 1965) and C. Chomsky (1969), in which changing one word changes the underlying relations holding between the terms in the sentence. The differences in the size of the eye-voice span (Wanat and Levin's dependent variable) for the unexpected and expected word types clearly showed the operation of reader expectations.

The third technique employed by the Levin group is in the work of Paul (in preparation), which also showed the operation of reader expectations at the level of phrase units. She constructed sentences in which the predictability of a particular kind of phrase, given a particular context, was varied. Each test phrase was prepared in varying degrees of visual clarity. She found that subjects could read a less-clear stimulus phrase if the context made it more predictable or "expectable." There was a trade-off between reader expectations and degree of clarity. The more expected the phrase, given the context, the lower the level of clarity necessary for perception. These studies by the Levin group show the operation of reader expectations (response biases) in the perception of word units and in the perception of phrase units.

The fourth technique used by the Levin group tests the reader's ability to recall certain structural details. It is related to Sachs's (1966) study. Sachs had subjects listen to a passage. Then, they heard a test sentence and were asked if that sentence were present in the passage they had just heard. She found that subjects had better recall for some structural details than for others; e.g., they seemed to be able to detect what she called "semantic" differences better than so-called "syntactic" differences. Levin and Wanat (1967) asked subjects to read sentences which were shown to them sequentially. The subject's task was to judge whether or not the two sentences in each pair were identical. Levin and Wanat found a relation between the structural predictability of the sentences and the subject's ability to make these judgments correctly.

The fifth technique exployed by the Levin group entailed monitoring readers' eye movements. In this research, already referred to in this paper, Wanat (1971) found that sentences that differed in structural predictability also differed in the amount of visual attention allotted to them by the reader. Less structurally predictable sentence types and less structurally predictable constituents within sentences required greater amounts of visual attention.

So far, we have concentrated on the first component in Model III. We will now turn our attention to the second component--confirmation or disconfirmation of the hypothesis formulated by the reader. Wanat and Levin (1970) theorized that the reader assigns priority to certain kinds of tentative structural descriptions in reading. With reading materials in which this initial hypothesis is confirmed, processing is facilitated and the reader is able to process more information, as shown by a larger eye-voice span. Given Levin's (1967) finding that the agent-included passive is more expected by the reader, Wanat and Levin (1970) theorized that when the reader encountered the beginning of a passive sentence, he would expect to encounter an agent after the verb. If such were the case in the sentence, Model III would predict that processing would be more efficient. The results of the experiment were as predicted by the model: The reader's eye-voice span following the passive verb was greater when the agent was present than when the agent was missing.

Two alternative explanations have been put forth which may account for these results. In an experiment using the same kinds of test materials (agent-included and agent-deleted passive sentences), Blumenthal (1967) and Blumenthal and Boakes (1967) found that the agent served as a more effective sentence-recall prompt than the nonagentive noun substitute. Blumenthal suggested that the agent had a more central relationship to the sentence than the nonagentive substitute, and it was this factor which made it a more effective prompt. Another alternative

explanation was mentioned by Wanat and Levin (1968). They theorized that the nonagentive form contains underlying structure additional to that contained in the agentive form. In the nonagentive sentence, the underlying agent slot is "understood," even though it does not occur lexically; also, an additional slot must be provided for the nonagentive phrase which was substituted. The alternative explanation provided by Wanat and Levin (1968) is parallel to the Miller, Bruner, and Postman (1954) view that the amount of information "going through" the perceiver is constant. Since the reader has to deal with more underlying information in the nonagentive form, he can pick up less lexical information.

Neither of these alternative explanations refutes Model III. The different interpretations are all compatible with the findings. The facts remain that Levin (1967) showed that when subjects are presented with these two forms, they favor, or give priority to, one of them, and that readers have longer eye-voice spans on the form that is given priority (Wanat & Levin, 1968, 1970). This same interpretation can be applied to the active/passive and left-embedded/right-embedded eye-voice-span studies discussed previously, and the same interpretation can be applied to Paul's results. The results of her study, like the results of the studies using the eye-voice-span technique, suggest that when the reader's initial hypothesis about the structure of the phrase is confirmed, processing is facilitated.

Model III holds that the reader responds (with "meanings" and with "sounds") on the basis of partial information. At the letter level, distinctive orthographic features and orthographic constraints are the forms of partial information (Smith, 1968). At the word level, the forms of information are the graphic stimulus (the word) and context (Ford & Levin, 1968; Levin & Ford, 1968; Weber, 1970). At the phrase level, they are the graphic stimulus (the phrase) and intrasentence constraints (Levin, Grossman, Kaplan, & Yang, in press; Levin & Kaplan, 1968, 1970; Paul, in preparation; Wanat & Levin, 1968, 1970).

The Levin group's findings that readers tend to assign priority to certain kinds of structural descriptions have important implications for models of language production and perception. Their results suggest that such models might have to include a means for assigning values to competing structural descriptions in cases where two or more interpretations may be possible, but one may be much more likely than another to be correct. The view that models for the perception and production of language may have to deal with the probabilities of occurrence of different structures is in direct opposition to the transformational-generative grammarians' refusal to take into account any probabilistic aspects of linguistic behavior.

The view that perceiver expectations operate in reading was discussed by Huey 70 years ago. He stated that it was the operation of reader expectations that permitted the more fluent processing of connected versus unconnected test materials. The contingencies between items in the connected materials enable the perceiver to anticipate what is coming. A model of the reading process incorporating response biases (or perceiver expectations) must be able to deal with both the partial nature of the material being processed and with the interplay between context and stimulus information. One model to consider is found in Giuliano (1963). In this model, initial stimulus information provides a context for subsequent stimulus information. Then, this package of information becomes a context for further stimulus information. A Markoff process might be an adequate basis for a model of the perception of language in reading. The operation of this model would switch from stimulus-state, to context-state, to stimulus, to context, etc. Chomsky (1957) has argued against a Markovian model for either the perception or production of language. Although Chomsky's own theory of linguistic structure makes use of hierarchical distinctions, his interpretation of the Markoff process limits the kinds of information units it can deal with to words. If one were to consider a model which could make hierarchical distinctions in the information dealt with, the validity of Chomsky's (1957) objections would be open to question.

It was noted in the preceding paragraph that a model of the reading process that incorporates reader expectations must deal with both the partial nature of the material being processed and with the interplay between context and stimulus information. There is the important question of whether or not there are large differences in the performance of subjects on different occasions or in the performance of different groups of subjects. That is, is there great consistency in the information attended to, in the amount of context or stimulus information necessary, and in the expectations themselves? Would the response biases of a child dealing primarily with an "elaborated code" differ from those of a child dealing primarily with a "restricted code" (Bernstein, 1964)? If so, in what ways would they differ? Since efficient readers operate on the philosophy that "less is more"--that is, using less information is more efficient--what are the behavioral characteristics of this middle ground between wanting to process every bit of information and guessing wildly on the basis of one cue? What is the optimal strategy for teaching the child how to process these higher-order structural relations? Does the teacher present highly regular lexeme-to-sentence-meaning correspondences, or does she try to get the child to work with a set for diversity, as Levin and Watson (1963) demonstrated with grapheme-phoneme correspondences?

The Levin group's research on reader expectations has dealt with higher levels of structure (the word as a stimulus

unit in the context of the sentence and the phrase as a stimulus unit in the context of the sentence). However, the same kind of model incorporating reader expectations or response biases might be appropriate for other levels of structure. If this kind of model is appropriate for the different levels of structure that the reader must deal with, a comprehensive model of the reading process might consist of a set of stimulus-to-context-to-stimulus-to-context processing chains. One chain would be operating at each level of structure. A unit at one level would be a "realization" of elements at another level. Such a model of reading would present the array of information that the reader must process in a way similar to Lamb's (1966) stratificational model of language.

NEEDED RESEARCH

Research that could provide important contributions to understanding the reading process would be the extension of the Project-Literacy studies developmentally to different social and linguistic groups. For the most part, the studies outlined above describe the behaviors of the mature reader. A description of accomplished reading is necessary so that one can characterize the goal that those learning to read--and those not learning to read--are aiming at. Successful programs for diagnoses and remediation require an adequate understanding of what constitutes successful reading. The same tasks outlined above can provide a description of how the reader develops each of the component skills in reading. These developmental data will allow one to characterize the progressive stages in the development of reading skill. Description of the stages in the development of cognitive skills and description of the stages in the development of linguistic skills have helped in the understanding of how children learn to talk and how they learn to think. A similar advance in understanding can come from a study of stages in the development of reading skill. Characterization of these stages would provide a very useful set of criteria for assessing reading disability and for developing strategies for remediation.

The children who very much need the concentrated and interdisciplinary study of reading specialists, psychologists, linguists, and sociologists are the bilingual and bidialectal youngsters in the ghettos and barrios and on the reservations. In addition, there are many other groups of children for whom English "school talk" is not their home language. Some of these are in Hawaii. The learning problems of children for whom "school English" is not their home language are immense. The linguistic, social, and psychological problems all feed into one another. The overwhelming majority of these children are asked to learn to read in a language that is strange to them. The child is presented with a graphic pattern and asked

to decode these marks into a set of sounds, morphological units, words, and syntactic patterns which he speaks only for a few minutes per day to his teacher, if he speaks to her at all. The problems of dealing with two language varieties that are rather similar are in some ways greater than the problems of dealing with two language varieties that are rather distinct, as anyone who has tried to learn Italian at the same time as Spanish, or Russian at the same time as Polish, can testify. Research is needed on the information-processing capacities and strategies of bicultural readers. How does the reading performance of a child for whom "school English" is a second dialect or language differ from the performance of a child who hears only this variety of English at home and school? Measures should be obtained for each of the components of the reading process presented in the models developed by the Project-Literacy group. The performance of subjects for whom there are major differences between home and reading languages (and, consequently, minor interference between the two language varieties) should be compared with the performance of subjects for whom there are minor differences between home and reading languages (and, consequently, major interference between the two language varieties). The performance of these two groups should be compared with the performance of subjects whose home language is the same as their reading language. These comparisons should be made at various stages in the development of reading skill.

There has been little research on the reading of bilinguals, and generally linguists have ignored the language varieties of ethnic minorities. With very few notable exceptions, this is still the case, and linguists continue to ignore language differences between groups by tying most of their theory and experimentation to the fiction of the "ideal speaker-hearer." One of the greatest educational challenges in this country would not exist if all that teachers had to contend with were "ideal readers." There are differences between the languages of different groups of people, and there are also linguistic differences within language communities, as for example, the differences between "elaborated" and "restricted" codes. Children from linguistic minorities comprise a great portion of our educationally disadvantaged. By studying how these linguistic differences affect their perceptual and cognitive strategies in reading and reading-related tasks, one can gain a better understanding of why these children experience problems with reading. Extension of the techniques discussed under each of the three Project-Literacy models may enable us to find out if--and how--these bicultural children are different from children with only one language:

1. in their internalized knowledge of the structure of the language they must read;
2. in their ability to locate the most informative areas of the test;

3. in the size of the unit they process;
4. in their ability to store verbal information;
5. in their ability to use different kinds of partial information in reading;
6. in the way their skills in reading in English are related to their skills in comprehending spoken English;
7. in the way their ability to understand written English is related to their ability to process pictorial information.

Developmental research on socially different and linguistically different children can provide information about the interaction between linguistic skills and perceptual-cognitive skills--a subject of interest to psychologists, linguists, and sociologists. This information would be interesting in its own right, but such research can also serve as a basis for providing tools for the diagnosis and remediation of reading disabilities.

REFERENCES

Bernstein, B. Aspects of language and learning in the genesis of the social process. In D. Hymes (Ed.), Language in culture and society. New York: Harper & Row, 1964.

Bever, T., & Bower, T. How to read without listening. In H. Levin et al., Project Literacy Report No. 6. Ithaca, N. Y.: Cornell University, 1966. Pp. 13-25.

Biemiller, A. J., & Levin, H. Studies of oral reading. II. Pronounceability. In H. Levin, E. J. Gibson, & J. J. Gibson (Eds.), The analysis of reading skill. A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968. Pp. 116-125.

Bishop, C. Transfer effects of word and letter training in reading. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 215-221.

Blumenthal, A. L. Prompted recall of sentences. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 203-206.

Blumenthal, A. L., & Boakes, R. Supplementary report: Prompted recall of sentences. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 674-676.

Brown, R. Psychology and reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. Pp. 164-187.

Chomsky, C. The acquisition of syntax in children from 5 to 10. Cambridge, Mass.: M.I.T. Press, 1969.

Chomsky, N. Syntactic structures. The Hague: Mouton, 1957.

Chomsky, N. Current issues in linguistic theory. The Hague: Mouton, 1964.

Chomsky, N. Aspects of the theory of syntax. Cambridge, Mass.: M.I.T. Press, 1965.

Chomsky, N. Phonology and reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. Pp. 3-18.

Clark, H. H. Some structural properties of simple active and passive sentences. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 365-370.

De Saussure, F. Course in general linguistics. New York: Philosophical Library, 1959.

Fodor, J. A., Garrett, M., & Bever, T. G. Some syntactic determinants of sentential complexity. II. Verb structure. Perception and Psychophysics, 1968, 3, 453-461.

Ford, B. L., & Levin, H. Homographs in a semantic context. In H. Levin, E. J. Gibson, & J. J. Gibson (Eds.), The analysis of reading skill. A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968.

Gibson, E. J. Learning to read. Science, 1965, 148, 1066-1072.

Gibson, E. J. A working paper summarizing theory-based research on reading and its implications for instruction. Unpublished paper, Department of Psychology, Cornell University, 1970.

Gibson, E. J., Gibson, J. J., Pick, A. D., & Osser, H. A developmental study of the discrimination of letter-like forms. Journal of Comparative and Physiological Psychology, 1962, 55, 897-906.

Gibson, E. J., Osser, H., & Pick, A. D. A study in the development of grapheme-phoneme correspondences. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 142-146.

Gibson, E. J., Osser, H., Schiff, W., & Smith, J. An analysis of critical features of letters, tested by a confusion matrix. In H. Levin et al., A basic research program on reading. Ithaca, N. Y.: Cornell University, 1963.

Gibson, E. J., Pick, A., Osser, H., & Hammond, M. The role of grapheme-phoneme correspondence in the perception of words. American Journal of Psychology, 1962, 75, 554-570.

Gibson, E. J., Shurcliff, A., & Yonas, A. Utilization of spelling patterns by deaf and hearing subjects. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970.

Gibson, J. J. The senses considered as perceptual systems. Boston: Houghton-Mifflin, 1966.

Giuliano, V. E. Analog networks for word association. In D. A. Norman (Ed.), Memory and attention. New York: Wiley, 1969. Pp. 166-174.

Gladney, T. A., & Kralee, E. E. The influence of syntactic errors on sentence recognition. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 692-698.

Goldman-Eisler, F. Psycholinguistics: Experiments in spontaneous speech. New York: Academic Press, 1969.

Goodman, K. S. Reading: A psycholinguistic guessing game. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 259-271.

Greenberg, D. Preferential attention to grammatical units. Unpublished paper, Department of Psychology, Cornell University, 1970.

Halle, M., & Stevens, K. N. Speech recognition: A model and a program for research. In J. A. Fodor & J. J. Katz (Eds.), The structure of language: Readings in the philosophy of language. Englewood Cliffs, N. J.: Prentice-Hall, 1964.

Hochberg, J. Components of literacy: Speculations and exploratory research. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. Pp. 74-89.

Hochberg, J., & Brooks, V. Reading as intentional behaviors. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970. Pp. 304-314.

Hockett, C. F. Analysis of English spelling. In H. Levin et al., A basic research program on reading. Ithaca, N. Y.: Cornell University, 1963.

Huey, E. B. On the psychology and physiology of reading. American Journal of Psychology, 1901, 12, 292-313.

Jakobson, R., Fant, C. G. M., & Halle, M. Preliminaries to speech analysis. Cambridge, Mass.: M.I.T. Press, 1969.

Judd, C. H., & Buswell, G. T. Silent reading: A study of the various types. Chicago: University of Chicago Press, 1922.

Kennedy, J. M. Regressive eye movements may depend on syntax. Unpublished paper, Department of Psychology, Cornell University, 1967.

Kolers, P. A. Three stages of reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. Pp. 90-118.

Lamb, S. M. Outline of stratificational grammar. Washington, D.C.: Georgetown University, 1966.

Lawson, E. A note on the influence of different orders of approximation to English language upon eye-voice span. Quarterly Journal of Experimental Psychology, 1961, 13, 53-55.

Levin, H. Unpublished study, Department of Psychology, Cornell University, 1967.

Levin, H., & Biemiller, A. J. Words vs. pseudo words. In H. Levin, E. J. Gibson, & J. J. Gibson (Eds.), The analysis of reading skill. A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968.

Levin, H., & Cohn, J. A. Effects of instructions on the eye-voice span. In H. Levin, E. J. Gibson, & J. J. Gibson (Eds.), The analysis of reading skill. A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968.

Levin, H., & Ford, B. L. Homographs vs. nonhomographs. In H. Levin, E. J. Gibson, & J. J. Gibson (Eds.), The analysis of reading skill. A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968.

Levin, H., Ford, B. L., & Beckwith, M. Homographs in grammatical frames. In H. Levin, E. J. Gibson, & J. J. Gibson (Eds.), The analysis of reading skill. A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968.

Levin, H., Grossman, J., Kaplan, E., & Yang, R. Constraints and the eye-voice span in right- and left-embedded sentences. Language and Speech, 1971, in press.

Levin, H., & Jones, D. Filled interword spaces and the eye-voice span. In H. Levin, E. J. Gibson, & J. J. Gibson (Eds.), The analysis of reading skill. A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968.

Levin, H., & Kaplan, E. L. Eye-voice span within active and passive sentences. Language and Speech, 1968, 11, 251-258.

Levin, H., & Kaplan, E. L. Grammatical structure and reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. Pp. 119-133.

Levin, H., & Turner, E. A. Sentence structure and the eye-voice span. In H. Levin, E. J. Gibson, & J. J. Gibson (Eds.), The analysis of reading skill. A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968. Pp. 196-220.

Levin, H., & Wanat, S. Reader sampling strategies. Unpublished paper, Department of Psychology, Cornell University, 1967.

Levin, H., & Watson, J. The learning of variable grapheme-to-phoneme correspondences. In H. Levin et al., A basic research program on reading. Ithaca, N. Y.: Cornell University, 1963.

Levin, H., & Williams, J. P. Basic studies on reading. New York: Basic Books, 1970.

Mackworth, N. H., & Bruner, J. S. How adults and children search and recognize pictures. Human Development, 1970, 13, 149-177.

Mackworth, N. H., & Morandi, A. J. The gaze selects informative details within pictures. Perception and Psychophysics, 1967, 2, 547-552.

Marchbanks, G., & Levin, H. Cues by which children recognize words. Journal of Educational Psychology, 1965, 56, 57-61.

Mehler, J., Bever, T. G., & Carey, P. What we look at when we read. Perception and Psychophysics, 1967, 2, 213-218.

Meltzer, N. S., & Herse, R. The boundaries of written words as seen by first graders. Journal of Reading Behavior, 1969, 1, 3-13.

Miller, G. A., Bruner, J. S., & Postman, L. Familiarity of letter sequences and tachistoscopic identification. Journal of General Psychology, 1954, 50, 129-139.

Neisser, U. Cognitive psychology. New York: Appleton-Century-Crofts, 1967.

Paul, D. Unpublished manuscript, Department of Education, Cornell University, 1971.

Pillsbury, W. B. A study in apperception. American Journal of Psychology, 1897, 8, 315-393.

Sachs, J. Recognition memory for syntactic and semantic aspects of connected discourse. Unpublished doctoral dissertation, University of California, Berkeley, 1966.

Schlesinger, I. M. Sentence structure and the reading process. The Hague: Mouton, 1969.

Smith, F. The use of redundancy and of distinctive features in the identification of visually-presented words. Unpublished doctoral dissertation, Harvard University, 1968.

Sorenson, R. T. Guidance of attention in character recognition: The effect of looking for specific letters. Unpublished doctoral dissertation, Cornell University, 1968.

Tulving, E., & Gold, C. Stimulus information and contextual information as determinants of tachistoscopic recognition of words. Journal of Experimental Psychology, 1963, 66, 319-327.

Venezky, R. L. A computer program for deriving spelling-to-sound correlations. In H. Levin et al., A basic research program on reading. Ithaca, N. Y.: Cornell University, 1963.

Venezky, R. L., & Calfee, R. C. The reading competency model. In H. Singer & R. B. Ruddell (Eds.), Theoretical models and processes of reading. Newark, Del.: International Reading Association, 1970.

Wanat, S. Linguistic structure and visual attention in reading. Unpublished doctoral dissertation, Cornell University, 1971.

Wanat, S., & Levin, H. The eye-voice span: Reading efficiency and syntactic predictability. In H. Levin, E. J. Gibson, & J. J. Gibson (Eds.), The analysis of reading skill. A program of basic and applied research. Ithaca, N. Y.: Cornell University, 1968.

Wanat, S., & Levin, H. Linguistic constraints in reader processing strategies. Paper presented to the Annual Meeting of the Eastern Psychological Association, Philadelphia, April 1970.

Weber, R. M. First-graders' use of grammatical context in reading. In H. Levin & J. P. Williams (Eds.), Basic studies on reading. New York: Basic Books, 1970. Pp. 147-163.

Williams, J. P., Blumberg, E. L., & Williams, D. V. Cues used in visual word recognition. Journal of Educational Psychology, 1970, 61, 310-315.

Williams, J. P., & Levin, H. Word perception: Psychological bases. Education, 1967, 87, 515-518.

Woodworth, R. S. Experimental psychology. New York: Holt, 1938.

8-179/ 8-179

MODELING THE EFFECTS OF ORAL LANGUAGE UPON READING LANGUAGE

Wendell W. Weaver and Albert J. Kingston

University of Georgia

INFORMATION AND CONTROL

American experimental psychology through its short history has derived most of its method and a large amount of its philosophy from the more exact sciences. This is true of that ubiquitous set of constructs, stimulus and response. Another assumption was made about stimulus and response; namely, energy exchange of one kind or another was viewed as the physical entity which was the concern of the psychological organism. Behavior is an act, the overt functioning of a muscle or gland (see Weaver, 1966). As interest in cognitive processes began to expand in the '50's and '60's, the analysis of exchanges of energy for such phenomena was inappropriate. While it is possible to estimate the energy output of the brain, the energy involved is low and does not directly affect information and control functions performed by the brain as long as it has a minimum necessary level.

Actually, this kind of problem was not unknown to the physical sciences. Physicists had long puzzled over Clerk Maxwell's demon (see Shannon & Weaver, 1961), a perpetual motion heat machine constructed with a rigid container. The container was divided into two compartments and in the dividing wall was an opening, closed by a small gate. A homunculus stood by the gate, and when he observed a particle moving faster than the average velocity of all particles approaching the gate, he would open the gate, letting the particle into compartment B. When he observed a particle moving slower than the average of all the particles, he would keep the gate closed, retaining the slow moving particles in compartment A. When the two compartments were connected to a heat engine, a perpetual motion machine was obtained. Norbert Wiener's (1943) analysis of the Maxwell demon is that the demon must receive information and act on it in order for the system to work. Therefore, though the demon reduces the entropy of the system, the information he must receive and the acting he must do adds the entropy back to the system. Due to these relationships, the system cannot maintain perpetual motion. The interesting point for those of us interested in cognitive

processes, however, is that information, when it is defined in probabilistic terms, can be demonstrated to have a physical effect which to the individual with scientific predispositions is the only "real" effect. It should also be observed that the demon, to a degree, exhibits sign behavior. In studying cognitive process, we are primarily interested in sign behavior, which though it operates at a low level of energy exchange, controls other, more powerful, energies within the system.

SIGN BEHAVIOR

Stimuli and Significants

The types of operations which are humanized by Maxwell's demon have been considered extensively by philosophers under the rubric symbiotics. The American pragmatist, Charles Pierce, did extensive analyses of sign behavior (see Morris, 1938). Psychologically, sign behavior is difficult to approach with our analytic tools because its major processes are covert. Only the effects of sign behavior are represented in overt behaviors. A number of psychologists and educators interested in reading have obviously felt the importance of dealing with this kind of behavior, though it is rarely mentioned specifically. Goodman (1969), for example, in dealing with miscues in the oral reading of early readers, proposes a kind of information-flow model to explain the ways in which early readers miscue. The final result is a kind of information-flow chart with the flow model resembling the various squares, rectangles, triangles, and various odd figures of the IBM flow chart, but actually representing different sorts of channel processing and exchanges which are hypothesized to occur within the organism. This model is begun by hypothesizing that the miscues are random processes which are assignable to the fact that visual input of graphic materials is sampled. At times, then, there are gaps or blanks in the sampling, and, in oral reading, these gaps or blanks sometimes come out as what appear to be misreadings.

There is a great deal of evidence for sampling processes in visual input. Studies of the behavior of subjects on rotor pursuit tasks indicate that this sampling is indeed a time-limited kind of behavior (Stroud, 1949). Geyer (1966) shows that time sampling of visual input occurs in eye movements in reading and hypothesizes that the sampling is constant. The fact that visual thresholds are highly raised during eye movements, whether the movements be large saccades or micro-movements, is another indication of a sampling characteristic. Nevertheless, in any information model based upon the characteristics of the stimulus input and upon certain observable coding phenomena occurring at the periphery of the perceptual process, there is little light thrown on the

processes by which physical graphic representations are elevated to the level of signs for the organism.

The perceptual theory of reading proposed by Eleanor Gibson (1970a, 1970b) is also confronted with this problem. No matter how precisely one traces the processes by which words or parts of words, immediate constituents, or sentences, or whatever linguistic unit one might study, one cannot explain the transmutation of the direct physical information into sign operations within the organism. As Osgood, Suci, and Tannenbaum (1961) note, the pattern of stimulation which is the sign is never identical with the pattern of stimulation which is the significant. The linguistic "bed" is not the bed one sleeps in. This last statement does not appear to be true for the child, however, or, perhaps, for the primitive. Developmentally, the sign seems to begin as an attribute of the thing (Brown, 1958). As mature conceptualization occurs, the sign becomes an entity apart. Signs may be manipulated, juxtaposed with other signs in order to explain, or describe, or solve a problem--all without any direct reference to the thing.

Brown (1958, p. 52) notes, "What the comprehension effect may be it is difficult to tell for this effect is hidden away inside the organism." This kind of statement is of little aid to the psychologist, however, especially for psychologists who are interested in model building. Models of the ephemeral which are themselves ephemeral are useless.

Oral Signs and Written Signs

There are, then, a number of assumptions, which linguists tend to equate with tested hypotheses, and which end up as having characteristics of "natural law." Chief of these is that oral language is the only possible language modality. It is, therefore, primary and all other forms secondary--well, let's face it--really, nonlanguage. On the other hand, with all the struggling of graduate students to meet the Ph.D. requirements in foreign language, there must have been one who learned to read the language without speaking it. In this case, one is enough. Most congenitally deaf people learn language; even deaf and blind people have learned language. Historically, it would be foolish to argue that oral language is not overwhelmingly preponderant, but it is just as counter to the evidence to argue that language without hearing and speech is impossible as it is to demonstrate psychologically that there are differences between oral and written language. The impact of language is in terms of information as well as in mode of presentation, and which has more power is a moot question.

This is not an academic question for reading models, for the high status of this attitude has led to a condescending

treatment of other language modalities--especially the visual. Recently, when more and more psychologists have been adopting linguistic propositions as psychological models of language, this had led to the common view documented above. Specifically, reading is nothing but a transduction of graphic forms into the oral language.

> This transduction is commonly considered to operate at the perceptual level with the underlying cognitive level only entered with the verbal sign. The process, then, is from graphic sign to verbal sign to cognitive interpretation, and the contemporary linguistic thinker seems to view this sequence as immutable [Weaver, 1969, pp. 107-108].

There are studies, however, which indicate that oral-productive language operations interfere with interpretive cognitive operations (Johnson, 1970; Weaver, Holmes, & Reynolds, 1970). Furthermore, it is well known that high school and college reading teachers have long tried to suppress vocalization in readers because of the interference vocalization causes with understanding.

Linguists argue that there is a simple one-to-one relationship between language production and interpretation. This is not at all apparent observationally. The child carries out verbal instructions before he speaks and he speaks words indicating interpretive relations, e.g., "because," before he understands the relation (Vygotsky, 1962). The argument goes that if one looks at "competence," performance differences disappear. The difficulty with this argument, to the empirical scientist anyway, is that competence is only known through performance.

The psychologists find great differences between language (speech or writing) and language interpretation. Encoding has a heavier information load as shown by Goldman-Eisler's (1961) investigations of pauses in speech. Pauses in reading aloud are short, related only to breathing and phrasing. Encoding involves "recall-like" operations; decoding seems to proceed as a rapid recognition.

The importance for a reading model is that analyses of speech acts do not account for writing and certainly not for auding and reading. The linguist draws evidence (as Suppes* says, "largely anecdotal") from a speech or writing corpus and is unsure whether he means to be psychological or not (Chomsky, 1968). However he resolves this issue, he excludes such psycologically important considerations as the nature of the memory store--a store reviewable depending upon the memory of the

---

*In debate with Jerry Fodor at APA Convention, Washington, D.C., 1968.

speaker (in a conversation), and not reviewable in the case of a formal speech such as this one.

There are other psychological considerations just as important as those mentioned above which are ignored by linguistic models of reading. I would say the most important of these are the relationships among language, concepts, and referential entities and relations in the physical world. I have been much impressed by the extent to which linguists have been able to reduce language analysis to an abstract, rational system. The goal seems to be to move even further until linguistic models approach abstract mathematical models. This does not seem to me to be an appropriate goal for psychologists. Language is learned by people to be used; it is learned because it is useful. It is learned as a part of a world which the organism accepts as real. A word means some thing or some action. Another word means relationships between things and actions. Reading is for use, also, and writing is not necessarily a secondary language form. In a completely deaf culture, writing and reading could occur. It is highly speculative to assume that reading is necessarily dependent upon oral language, or that if oral language is a mediator in learning to read, it remains so for the accomplished reader.

Categories and Information

One way to make sign behavior less ephemeral is to conceptualize it as some kind of information processing; that is, some process which takes the sensory data from an aural or a graphic representation and through some logical neural net relates the data to schemas already existing within the organism. Again, some substance seems lent to a model when categories of certain kinds are the organizational elements of the schemas. It does not appear likely that these categories exist in something like a work-to-thing. For one reason, this seems enormously inefficient, even for the very inefficient nervous system. Furthermore, the word as we know it externally does not exist until the coordination of the vocal musculature forms a unitary sound. Sign behavior seems to require the positing of hierarchically organized kinds of categorical arrangements. As Brown (1958) points out, it is also important to have an empty category. One hears a word for the first time and it is not understood. What is understood is that the substance of the category is to be filled in with further experience with that word in its many contexts. Jenkins (1965) considers concepts to be categories; i.e., a system of relationships defined by rules. Language, then (oral and reading language), operates by a set of categories--syntactical, semantical, phonological, morphological, and probably many others. It should be emphasized that these categories, as are all our scientific categories, are

inventions. In this case, then, they may or may not be psychological. The demonstration of the psychological reality of these categories in oral and reading language constitutes a great part of our research tasks.

ORAL LANGUAGE AND BEGINNING READING

An adult examining oral and written language becomes highly impressed by the characteristics they share. He finds the evidence so overwhelming that he tends to view written and oral language as identical in nature. This is especially true if oral-language samples are transposed to written form and these compared linguistically to other written production. Typically such a procedure tends to divorce the language from its psychological reality. It is doubtful, however, that the naive learner of a written language, i.e., a naive reader, is aware of this apparent relationship. In fact, an advantage claimed by adherents to the "Language Experience Approach" to beginning reading instruction is that the system helps the child to see the relationship of his oral language to written language. Even such a common appearing concept as "word" may not be in the concept storage of young children (see Meltzer & Herse, 1969).

One can argue that even if the commonalities of features of written and oral language seem to impress an adult, it does not necessarily follow that the six-year-old child will note the same common elements. As many researchers have discovered, children do not function linguistically or intellectually in the same manner as adults.

A number of readily apparent differences in learning oral natural language and in learning to read one's language can be noted. First, the young child and infant learns his natural language in the "real" environment of which he is a part. Much of his oral language is learned in relationship to his needs, which are expressed by significant others and himself. At an early age his attempts at discriminating the speech of others or attempting to express his own needs are reinforced positively and with compounding consistency. Typically, the more responses he makes and the more actively he engages in language learning, the more positive are the schedules of reinforcement that ensue. In the schoolroom, reinforcement for learning to read language is neither so regularly nor so positively reinforced. Again, in learning one's language orally, it should be noted that the period for learning extends over a period of many years. The average child can discriminate certain aspects of oral language at approximately six months of age. Six months later, at one year of age, the child can produce words (McCarthy, 1954). By 18 months of age, the typical child can communicate many of his needs, although he may use gestures extensively. From that

period until school entrance, all aspects of language develop constantly. By contrast, the acquisition of much reading language is telescoped over a period of three years of the primary grades. Although some reading specialists believe reading skills require a lifetime to develop, most persons regard the primary grades as the essential or critical years for "learning to read." Certainly the fourth-grade child who has not mastered fundamental reading skills is doomed to a school life of considerable difficulty. It also should be noted, however, that for any child--regardless of his socioeconomic position, familial position, or other status--failure to develop oral communication skills represents a severe hardship in learning, socialization, or the mastery of any developmental task composed by the major or his own particular subculture. Hence, he functions under considerable stress or need to master oral language skills. In contrast, many children either fail to recognize the need to acquire reading language or are not sufficiently motivated to achieve the desired goals.

In learning oral language, it should be noted, the young child does not learn "rules." Rather, he behaves and is reinforced accordingly. He learns how to act, not how he acts. His models speak, he speaks. He can say some things before he "knows" what he is saying and he can do other things before he can say what he is doing (Vygotsky, 1962). Language is intimately related to intelligence and thought. Piaget and Inhelder (1969) argue, however, that while language is necessary for the highest levels of conceptual thinking, language and conceptualization are separate functional systems and many elemental as well as certain elaborate concepts are developed without language playing an essential role.

Finally it should be noted that many linguists feel that any time a language is transposed from an oral to a written form, some damage or alteration ensues. They argue that such important characteristics as phonology, intonation, pauses, etc., are lost. It should be noted, however, that some language learners (usually mature) can move successfully in language learning from written forms to oral forms (Durkin, 1966). This is noticeable in the language achievements of the deaf and hard of hearing as well as certain learners of second languages.

Apparently the transfer of "meaning" from spoken to graphic representation may not be the direct, simple operation commonly assumed. Nor does it follow that the ability to demonstrate language facility is a necessary antecedent condition to learning reading behavior. Even if the linguist is correct in hypothesizing that reading is merely a transduction of verbal symbols, the process by which the human performs this process is by no means simple.

Those who teach children to read have no doubt that oral language is crucial in learning to read. Furthermore, the feeling is, usually, the better the oral language accomplishment, the better the reading accomplishment. Robinson (1955) says that the extent to which the child uses the language with which he reads is basic to reading success. In a more formal research discussion, Calfee and Venezky (1968) examined the factors reported in the literature as being involved in beginning reading. There was little evidence given here for maintaining the concept, "component skills of reading." Calfee and Venezky concluded that in all the measurements of these skills there tended to be only two general factors which were adequately separated: (1) the ability to follow instructions and (2) a general verbal factor. This general verbal factor seems the kind of correlation that bridges oral language and reading language. It is a far cry, however, from a hypothesized general ability factor which appears in practically all measurement studies involving language (generally identified by a high loading on a vocabulary component) to a specific oral language ability which harbingers success in reading. Tests attempting to show a variety of language components such as the Illinois Test of Psycholinguistic Abilities do not show side separation of supposedly different subtests when subjected to correlational analysis. Quereshi (1967) found a developmental factor in the subtest of the ITPA with correlations at later ages focusing at .43. It is very questionable, however, that the ITPA, if subjected to a rigorous procedure such as the Campbell-Fiske analysis, would separate distinct factorial components. In short, while no one would argue that reading behavior develops in the child with the basis in oral language, specifics of that dependency upon oral language have not been identified.

In the light of this sort of information about the operation of oral language in reading, it is difficult to see how such injunctions as "the syntactic ability of the child ought to be improved because the concentration at the present is upon his vocabulary" can be maintained (see Fleming, 1968). If the effect of oral language in general is not understood, certainly the effect of syntax is even more obscure. Another palliative for the difficulty of children in learning to read is proposed by John Downing (1970). Downing thinks that cognitive confusion and lack of system in beginning reading is a basic characteristic of reading disability. He finds that because children have vague ideas about how people read and have special difficulty in understanding the purposes of written language, they have difficulty reading. This same concern is indicated by such papers as that of Meltzer and Herse (1969) where it is found generally that first graders are unable to discriminate boundaries of the word and thus have reading difficulties.

Another sort of approach to the problem of the effect of oral language on reading is in proposals put forth by Marquardt (1964). Marquardt speculates that the spoken word may be analyzed into at least two distinct styles of behavior: (a) conversation, and (b) spoken prose, which consists of monologue and reading aloud. Marquardt hypothesizes that reading is much more like spoken prose than like conversation. He goes further to speculate that an appropriate educational sequence might be to move from conversation to spoken prose and then to reading.

If oral-language dimensions can be shown to maintain their characteristics when reading dimensions are substituted, these variables can be considered to be the same across modalities. Reading specialists (and most linguists) have assumed that a child's success in learning to read is dependent upon an "adequate" oral language. This has seemed so obvious that few definitions of "adequate" have been forthcoming. Fries (1952, p. 119) states, "The process of learning to read in one's native language is the <u>process of transfer</u> from auditory sign for language signals which the child has already learned to the new visual signs for the same signals [italics are Fries']." Bloomfield (1946), one of the earliest linguists to discuss reading, stressed that the reading act consists of transforming written symbols into sounds. Ilg and Ames (1950), Soffietti (1955), Lefevre (1964), and Carroll (1964) have, in essence, supported this view.

Weaver and Kingston were thinking of these rather overwhelming opinions when they began a set of studies to attempt to separate certain language constructs (e.g., structure and abstraction) into verified entities. In the first year, the Campbell-Fiske construct--discriminant validity analysis--was applied to several oral and written language dimensions (Campbell & Fiske, 1959). When the data were in, the separation was not among the constructs but between the oral measurement tasks and the written measurement tasks (Weaver & Kingston, 1971).

All the measures used during the first year were revised, a number of new measures were selected, and during the second year another attempt was made to validate the constructs. Again the constructs hypothesized did not separate, while the method of testing, oral or written, was the main source of variation. This year, oral-language variables which are reflected in reading success are still being sought, but the Campbell-Fiske analysis has been abandoned as too costly for this purpose.

Any observant analysis of the learning tasks faced by the child shows considerable differences in the learning conditions imposed by oral and written language. In learning oral language, the child functions in his life situation.

Language learning is a "must." The child's speech emissions are usually reinforced immediately; his understanding of messages to him obtains immediate reward. He learns hour by hour over years in situations where language, referents, and meanings are in one system. His lessons are not intensive, compressed, and divorced from life, as "learning-to-read" situations tend to be. If a child in learning to read leans heavily on the oral language, this does not at all imply that oral language and reading language share the same psychological operations when the child has made the step to reading proficiency. In fact, if the child's reading ability does not soon grow beyond his oral-language capacity in terms of speed and processing, and volume and accuracy of information, his learning facility is questioned.

ON AN ECLECTIC MODEL OF READING

Building an eclectic model of reading presents problems because many of the most important component parts are missing. We do not know, for example, how an electrochemical impulse becomes "meaning." As one looks at the results of this literature search, he finds that much is known about a few things and little is known about a lot of things. Unfortunately, the little that is known includes some of the most necessary variables. Our assignment was to conjure up a model, but we are not sure of its value because of the paucity of information necessary to build a model. Although we located syntax-to-meaning models, we found no referent-to-meaning models. Such a potential model is easily conceived in verbal terms. Consider the following set of propositions.

1. Language is first learned by relating perceptual entities to verbal signs; i.e., words--oral, visual, or tactile.

2. At the beginning, the verbal sign is an attribute of the perceptual entity.

3. Abstract and figurative language develops as analogies, similes, etc., are constructed from perceptual entities and their verbal signs, and are assigned new verbal signs.

4. The morpheme is the unit of meaning.

5. Free morphemes and bound morphemes develop in different functional systems.

6. Bound morphemes and functors (words forming exhaustive categories; e.g., prepositions) are in the same functional system.

7. Speech and listening involve some different processes, as do writing and reading.

8. Oral language and written language are interrelated in that they use the same concept "storage."

9. Reading process and oral-language process diverge as the reader becomes more adept.

10. Access to concept storage becomes directly available for the graphic sign as reading skill increases.

11. Morphemes can be concatenated to form new units of meaning; e.g., house means something, white house means something else, large white house means something else again.

12. Morphemes and concatenations of morphemes can be related by drawing items from a learned set of relational classes.

    Example: a. white house
    b. river road
    c. the
    d. on
    e. The white house on the river road.

13. Syntactical rules are built from the relationship of entities and phenomena in the physical word.

14. Concatenation of morphemes and relations among classes are juxtaposed by the organism's conceptions of what the verbal signs mean in the physical world. Syntax as the linguists abstract that construct, then, is an artifact of the organism's information processing, not the cause of it.

There is some evidence in the literature for each of the propositions listed above. There is contradictory evidence in the literature for each of the propositions listed above. Our conclusion is that the time is not propitious for model building if the model is to arise from tested theory. There are too many contradictory findings which require empirical resolution in order that a consistent set of theoretical propositions might be drawn. Elaborate models cut out of whole cloth are of dubious value to science (see Kingston, 1971).

REFERENCES

Bloomfield, L. Language. New York: Holt, Rinehart, & Winston, 1946.

Brown, R. Words and things. New York: Free Press, 1958.

Calfee, R. C., & Venezky, R. L. Component skills in beginning reading. In K. S. Goodman & J. T. Fleming (Eds.), Psycholinguistics and the teaching of reading. Newark, Del.: International Reading Association, 1968.

Campbell, D. T., & Fiske, D. W. Convergent and discriminant validation by the multitrait-multimethod matrix. Psychological Bulletin, 1959, 56, 81-105.

Carroll, J. B. The analysis of reading instruction: Perspectives from psychology and linguistics. In E. R. Hilgard (Ed.), Theories of learning and instruction. Chicago: National Society for the Study of Education, 1964.

Chomsky, N. Language and mind. New York: Harcourt, Brace & World, 1968.

Downing, J. The development of linguistic concepts in children's thinking. Research in the Teaching of Reading, 1970, 4, 5-19.

Durkin, D. Children who read early: Two longitudinal studies. New York: Teachers College Press, 1966.

Fleming, J. T. A pilot study of children's perception of different speech forms. Paper read at the American Educational Research Association annual convention, Chicago, 1968.

Fries, C. C. The structure of English. New York: Harcourt, Brace & World, 1952.

Geyer, J. Perceptual systems in reading: A temporal eye-voice span constant. Unpublished doctoral dissertation, University of California, Berkeley, 1966.

Gibson, E. J. Perceptual learning and the theory of word perception. Paper read at the American Psychological Association annual convention, Miami, 1970. (a)

Gibson, E. J. A working paper summarizing theory-based research on reading and its implications for instruction. (Mimeographed) 1970. (b)

Goldman-Eisler, F. Hesitation and information in speech. In Symposium on information theory. London: Butterworths, 1961.

Goodman, K. S. A study of oral reading miscues that result in grammatical re-transformations. Final Report, Project No. 7-E-219, U.S.O.E., June 1969.

Ilg, F. L., & Ames, L. B. Developmental needs in reading behavior. Journal of Genetic Psychology, 1950, 76, 291-312.

Jenkins, J. J. Meaningfulness and concepts: Concepts and meaningfulness. In H. J. Klausmeier & C. W. Harris (Eds.), Analysis of concept learning. New York: Academic Press, 1965.

Johnson, D. C. The effects of reading and punctuation variations upon reading comprehension. Unpublished master's thesis, University of Georgia, 1970.

Kingston, A. J. Ephemeral models and disjunctive categories. Paper read at the International Reading Association annual convention, Atlantic City, 1971.

Lefevre, C. A. Linguistics and the teaching of reading. New York: McGraw-Hill, 1964.

McCarthy, D. Language development in children. In L. Carmichael (Ed.), Manual of child psychology. New York: Wiley, 1954.

Marquardt, W. F. Language interference in reading. The Reading Teacher, 1964, 18, 214-218.

Meltzer, N. S., & Herse, R. The boundaries of written words as seen by first graders. Journal of Reading Behavior, 1969, 1, 3-13.

Morris, C. Foundations of the theory of signs. International Encyclopedia of Unified Science (Chicago), 1938, 2, 3-4.

Osgood, C. E., Suci, G., & Tannenbaum, P. The logic of semantic differentiation. In S. Saporta (Ed.), Psycholinguistics. New York: Holt, Rinehart, & Winston, 1961.

Piaget, J., & Inhelder, B. The psychology of the child. New York: Basic Books, 1969.

Quereshi, M. Y. Patterns of psycholinguistic development during early and middle childhood. Educational and Psychological Measurement, 1967, 27, 353-365.

Robinson, H. M. Factors which effect success in reading. Elementary School Journal, 1955, 55, 263-269.

Shannon, C. L., & Weaver, W. The mathematical theory of communication. In S. Saporta (Ed.), Psycholinguistics. New York: Holt, Rinehart, & Winston, 1961.

Soffietti, J. P. Why children fail to read: Linguistic analysis. Harvard Educational Review, 1955, 25, 63-84.

Stroud, J. Cybernetics. In H. Von Foerster (Ed.), Transactions of the society. New York: Macy, 1949.

Vygotsky, L. S. Thought and language. Cambridge, Mass.: M.I.T. Press, 1962.

Weaver, W. S. Units of measurement and units of language. Paper presented at symposium on the technology of written instruction. U.S. Office of Naval Research, Columbia University, New York, 1966.

Weaver, W. W. Linguistic assumptions and reading implications. In G. B. Schick & M. May (Eds.), Eighteenth Yearbook of the National Reading Conference. Milwaukee, Wis.: Marquette University Press, 1969. Pp. 107-112.

Weaver, W. W., Holmes, C. C., & Reynolds, R. R. The effect of reading variation and punctuation condition. Journal of Reading Behavior, 1970, 2, 75-84.

Weaver, W. W., & Kingston, A. J. Assessment of oral-written language behaviors with the Campbell-Fiske analysis procedure. Paper read at a symposium on the Information-Flow Theory of Learning to Read and the Reading Process at the American Educational Research Association annual convention, New York, 1971.

Wiener, N. Cybernetics. New York: Wiley, 1948.